THE UNIVERSITY OF ALBERTA

THE MANNVILLE GROUP (LOWER CRETACEOUS) OF THE HUSSAR AREA, SOUTHERN ALBERTA

by

© P. A. ACHAM

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Mannville Group (Lower Cretaceous) of the Hussar area, Southern Alberta", submitted by Patrick Anthony Acham, B.A., in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

The Mannville Group of the Hussar area is divided into a lower McMurray Formation and an upper Fort Augustus Formation. Relief on the sub-Cretaceous unconformity, the topographic features of which were controlled by the nature of the subcropping Paleozoic formations, is of the order of 300 to 400 feet. Valleys on the sub-Cretaceous surface were occupied by westerly-flowing streams which probably joined a major valley system which flowed northerly over wide flood plains. Mannville sedimentation was brought to a close in late Albian time with the advance of a boreal sea which transgressed southward to join with a sea from the Gulf of Mexico forming the extensive Colorado sea of the interior of North America.

Lower Mannville (McMurray Formation) sandstones are quartz sandstones and lithic sandstones with rock fragments constituting as little as 5 percent of the framework and feldspar less than 1 percent. Upper Mannville (Fort Augustus Formation) sandstones range from lithic sandstone at the base to rock fragment sandstone at the top; rock fragments constituting up to 66 percent of the framework, and feldspar becoming abundant towards the top.

The average composition of 75 shales studied using the X-Ray fluorescence method is 56.0% SiO_2, 1.06% MgO, 18.97% Al_2O_3, 2.29% K_2O, 0.86% CaO, 2.66% Fe_2O_3, 137 ppm Rb, 188 ppm Sr. The Rb/Sr ratio of 0.73 is somewhat higher than data from other shales. The Rb/K ratio varies from about 0.005 for shales formed in a continental environment to 0.007 for normal marine shales.

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Core examination facilities of the Alberta Energy Resources Conservation Board were placed at the writer's disposal.

E. Zan and M. Priestly-Wright assisted with drafting and the manuscript was typed by R. Van Der Veen.

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Chapter 1

INTRODUCTION

Purpose and Location of Study

This study was undertaken to determine the provenance and environment of deposition of the Lower Cretaceous Mannville Group of the Hussar area. No attempt was made to determine reservoir geometry and fluid distribution of individual accumulations nor was any attempt made to determine the mechanism controlling hydrocarbon accumulations. The author seeks to describe the significant Lower Cretaceous rock groups and to outline the regional environments within which the important oil and gas producing sandstones of the Hussar field occur.

The Hussar area (Figure 1) is located in the southern Alberta Plains approximately 50 miles east of Calgary. The Hussar field and the area of the present study is shown in Figure 2.

Regional Geologic Setting

The Canadian Plains occupy the site of what was in Cretaceous time a broad depositional trough extending from the vicinity of the present Rocky Mountain Trench to east of the Manitoba escarpment. In early Cretaceous time "...the Mannville Group was deposited over a gently undulating series of broad valleys and rounded ridges sculptured mainly in Paleozoic carbonates" (Williams, 1960, p. 13). Lower Cretaceous sediments include large volumes of deltaic and

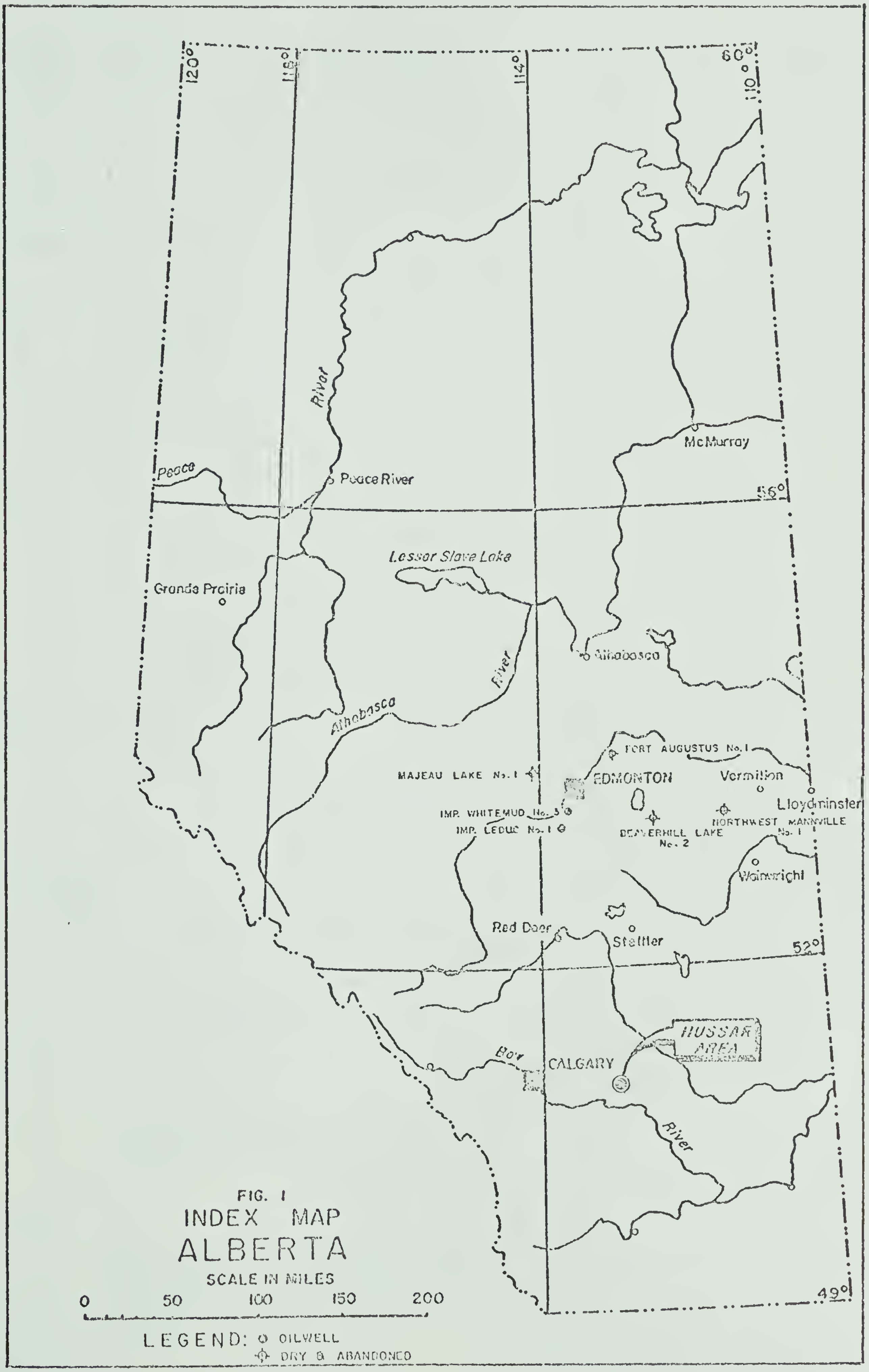
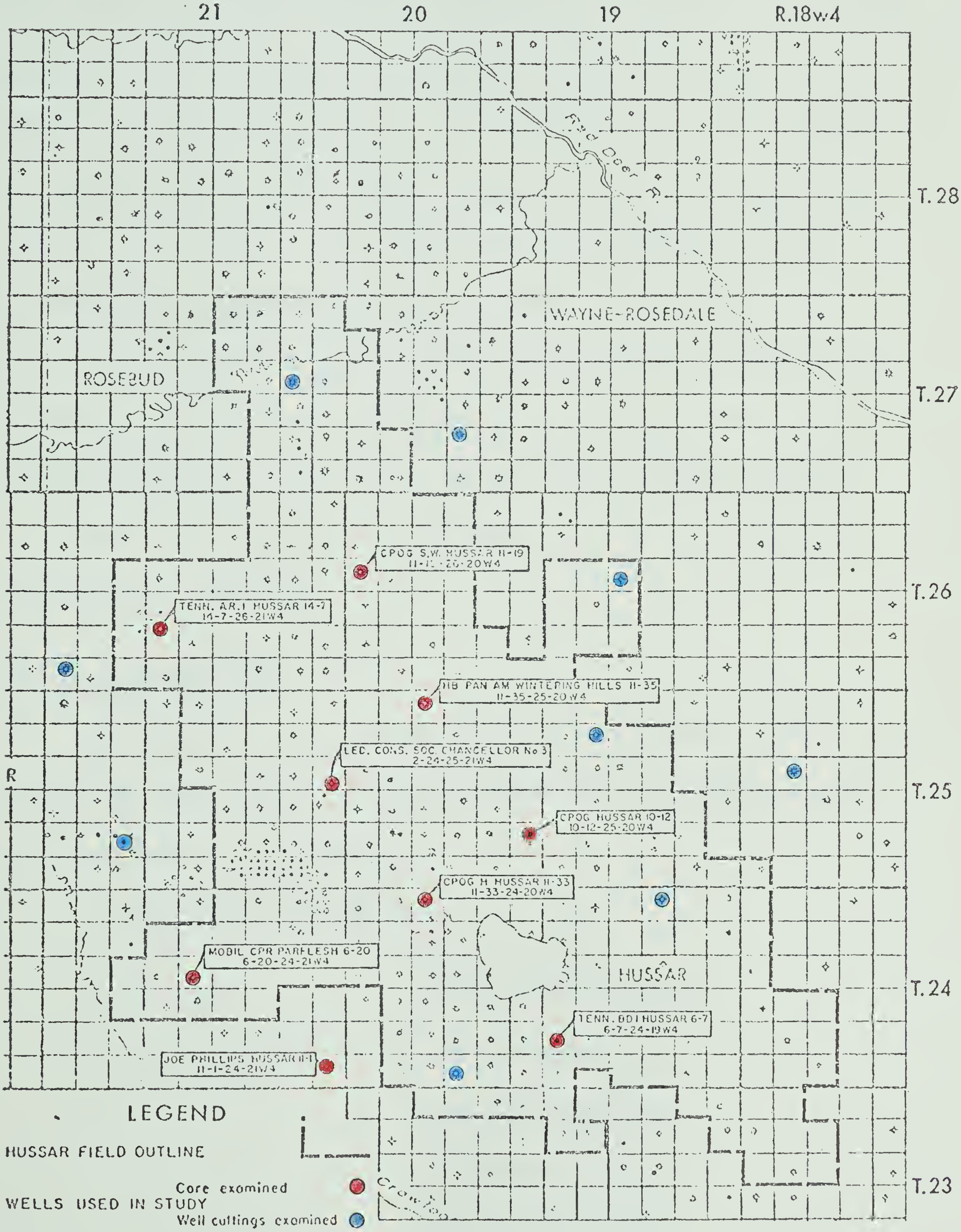


FIG. I
INDEX MAP
ALBERTA



LEGEND

HUSSAR FIELD OUTLINE

WELLS USED IN STUDY
- Core examined
- Well cuttings examined

LOCATION OR DRILLING WELL

OIL WELL

GAS WELL

ABANDONED WELL

HUSSAR AREA

LOCATION OF WELLS

SCALE IN MILES

0 2 4 6 8

FIG. 2

alluvial clastics derived from a rising borderland to the west. The Canadian Shield to the northeast also supplied sediments and its contribution was probably significant in early Cretaceous time (Williams, Baadsgaard and Steen, 1962). According to Rudkin (1964, p. 167), "... the non-marine beds of the Foothills and Plains regions were progressively onlapped by a southward transgressing boreal sea which deposited marine shales and to varying degrees winnowed and redistributed the earlier non-marine deposits." The Hussar field which produces both gas and oil from the Mannville Group lies in an erosional low on the sub-Cretaceous surface at the western edge of an area of northwest-southeast trending Cretaceous reservoirs. The field outline is shown in Figure 2.

Mesozoic and Paleozoic beds dip slightly north of west at 20 feet and 35 feet per mile, respectively.

Material and Methods Used

Samples for this study were obtained from the Alberta Energy Resources Conservation Board, Calgary. The samples come from stratigraphic intervals cored in the following wells (Figure 2):

1. Tenn BD 1 Hussar No. 6-7
   Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M

Elevation:	3030 feet (Kelly Bushing)
Cored Intervals:	4103 feet to 4147 feet
	4205 feet to 4245 feet
	4370 feet to 4420 feet
	4506 feet to 4701 feet

2. CPOG H. Hussar No. 11-33
   Lsd. 11, Sec. 33, Twp. 24, Rge. 20, W4M

Elevation:	2994 feet (Kelly Bushing)
Cored Interval:	4544 feet to 4609 feet

3. Joe Phillips Hussar No. 11-1
   Lsd. 11, Sec. 1, Twp. 24, Rge. 21, W4M

Elevation:	2834.5 feet (Kelly Bushing)
Cored Interval:	4410 feet to 4527 feet

4. Mobil CPR Parflesh No. 6-20
   Lsd. 6, Sec. 20, Twp. 24, Rge. 21, W4M

Elevation:	2922 feet (Kelly Bushing)
Cored Intervals:	4627 feet to 4687 feet
	4710 feet to 4751 feet

5. CPOG Hussar No. 10-12
   Lsd. 10, Sec. 12, Twp. 25, Rge. 20, W4M

Elevation:	3024 feet (Kelly Bushing)
Cored Interval:	4499 feet to 4719 feet

6. HB Pan Am Wintering Hills No. 11-33
   Lsd. 11, Sec. 33, Twp. 25, Rge. 20, W4M

Elevation:	3132.1 feet (Kelly Bushing)
Cored Interval:	4720 feet to 4850 feet

7. Leduc Consolidated Socony Chancellor No. 3
   Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M

Elevation:	2996 feet (Kelly Bushing)
Cored Interval:	4621 feet to 4838 feet

8. CPOG SW Hussar No. 11-19
   Lsd. 11, Sec. 19, Twp. 26, Rge. 20, W4M

   Elevation: 3047 feet (Kelly Bushing)

   Cored Interval: 4675 feet to 4726 feet

9. Tenn Ar 1 Hussar No. 14-7
   Lsd. 14, Sec. 7, Twp. 26, Rge. 21, W4M

   Elevation: 2838.9 feet (Kelly Bushing)

   Cored Interval: 4735 feet to 4797 feet

In addition, electric well logs from these nine wells and all wells drilled in the area prior to June 1969 were used to supplement the data obtained from the cores and in constructing the structure contour map on the Base of the Fish Scales marker (Figure 4), the Lower Cretaceous isopach map (Figure 6) and the structure contour map on the Paleozoic surface (Figure 5). Unfortunately, in many cases, coring was begun too low in the section to give a good sampling of the Upper Mannville. Therefore, well cuttings from nine more wells in the area were examined to provide additional data on the Upper Mannville.

Megascopic descriptions of cores were made with the aid of a binocular microscope. Appropriate sandstone intervals were sampled for the preparation of thin sections and shale samples were collected for X-ray fluorescence analysis. Megafossils were collected from the cores wherever present and identified by Dr. C. R. Stelck of the Department of Geology, University of Alberta.

Locations of all samples are given in Appendix A.

Wentworth's size classification of sedimentary particles (Krumbein and Pettijohn, 1938) was used as was Powers' (1953) scale of roundness. The termi-

nology introduced by McKee and Weir (1953) for stratification in sedimentary rocks has been used throughout.

Previous Work

Nauss (1945, 1947) introduced the name Mannville Formation for a succession of Lower Cretaceous continental and marine strata lying between the eroded surface of the Paleozoic and the marine Colorado shale in the subsurface in the Vermilion-Wainwright area of east-central Alberta (see Figure 1). Six members were differentiated in Northwest Mannville No. 1 (Lsd. 1, Sec. 18, Twp. 50, Rge. 8, W4M), mainly on the presence or absence of dark minerals in the sandstones, distribution of marine fossils and the occurrence of coal seams. These members in ascending order are:

Dina Member:	Quartz sandstone, dark grey shale, light grey siltstone, sideritic nodules and plant remains; 115 feet thick.
Cummings Member:	Shale, black to dark grey, with some siltstone, "salt and pepper" sandstone, coal, abundant pyrite, and Foraminifera; 88 feet thick.
Islay Member:	Quartz sandstone, with some shale partings; 10 feet thick.
Tovell Member:	"Salt and pepper" sandstone, dark to medium grey shale and siltstone, with a few plant remains; 78 feet thick.

Borradaile Member:	Quartz sandstone, dark to medium grey shale, and buff siltstone; 29 feet thick.
O'Sullivan Member:	"Salt and pepper" sandstone, dark to medium grey shale and siltstone, with sporadic thin coal seams; 55 feet thick.

Within the type area, the Mannville Formation varies in thickness from 250 feet to 640 feet.

Wickenden (1948) proposed a threefold division of the Mannville Formation for the Lloydminster region (Figure 1) and considered it to have been deposited as a delta on the western margin of a shallow seaway. His lower unit is approximately equivalent to Nauss' Dina, his middle unit of marine brackish water sediments includes Nauss' Cummings, Islay, Tovel and part of the Borradaile Members. Wickenden's upper unit includes the upper part of the Borradaile and the O'Sullivan Members.

Kidd (1948) noted that the Dina Member was absent from the Beaverhill Lake No. 2 well (Lsd. 11, Sec. 11, Twp. 50, Rge. 17, W4M) which lies approximately 100 miles west of the type Mannville, but was unable to recognize any of the other members.

In 1949, Layer described the section found at Imperial Leduc No. 1 (Lsd. 5, Sec. 22, Twp. 50, Rge. 26, W4M) (Figure 1) and divided the Lower Cretaceous rocks into three parts. These are in ascending order:

Quartz Sand Series	175 - 350 feet thick
Glauconitic Sand Series	255 feet thick
Coaly Series	230 feet thick

Also in 1949, Andrichuk studied the section encountered in the Majeau Lake No. 1 well (Lsd. 12, Sec. 1, Twp. 57, Rge. 3, W5M) which lies approximately 45 miles northwest of Edmonton. He divided the formation into a lower predominantly marine and brackish unit and an upper continental unit. He did not recognize Layer's "Quartz Sand Series" in his study area.

Loranger (1951) noted that the base of the "Glauconitic Sand Series" as described by Layer (1949), contained an abundance of ostracods, pelecypods and gastropods in the Edmonton area. She referred to this interval as the Metacypris persulcata zone or "ostracod zone", and based correlations in central and southern Alberta, including the foothills on this fauna.

In 1952, Badgley raised the Mannville Formation of the Edmonton - Lloydminster area to group status and divided it into three formational units recognized in outcrops to the northeast on the Athabasca River (McLearn, 1917). These are in ascending order, the McMurray, Clearwater and Grand Rapids Formations. He excluded from this definition of the Mannville Group an underlying succession of detrital and residual matter deposited in the depressions in the Paleozoic surface, for which he proposed the name Deville Formation.

Glaister (1959) integrated the published data with the available subsurface data in an attempt to show the regional correlation of lithologic units within the Lower Cretaceous, particularly between the subsurface and outcrop areas and to outline broadly the facies patterns. He placed the boundary between the upper and lower Mannville "Formations" at the base of the "Glauconitic sandstone member".

Williams (1960) accepted Badgley's threefold division of the Mannville Group but included in it the underlying Deville Formation as the basal member of the McMurray Formation. He called the middle part of the McMurray Formation the Ellerslie Member after Hunt's (1950) unit which embraces approximately the same stratigraphic interval, and the upper part the "Calcareous" member, an informal term proposed by Glaister to replace the Metacypris persulcata zone or "ostracod zone" described by Loranger (1951).

Price (1963), found a comparatively thin accumulation of Lower Cretaceous rocks in southeastern Saskatchewan which he considered to have been deposited on a higher eastern shelf. He divided these rocks into two major groups, the upper or Ashville Group which contains marine fossils and glauconite beds - conspicuously absent in the underlying "basal Cretaceous sandy group". He further subdivided the basal group into the Cantuar and Pense Formations (see Table 1).

From his investigations, Price found a part of the Blairmore Group to the west to be roughly continuous with the basal sandy group to the east, most of which may be equivalent to the Mannville Group of eastern Alberta. He drew the boundaries of basal Cretaceous groups according to the arbitrary cut-off principle described by Wheeler and Mallory (1953).

Rudkin (1964), on the basis of electric logs and lithology, divided the Mannville Group into a lower and an upper unit, each representing a distinct phase of sedimentation. He considers the Lower Mannville to be essentially a basal "fill" deposit representing the first sedimentation following a long period

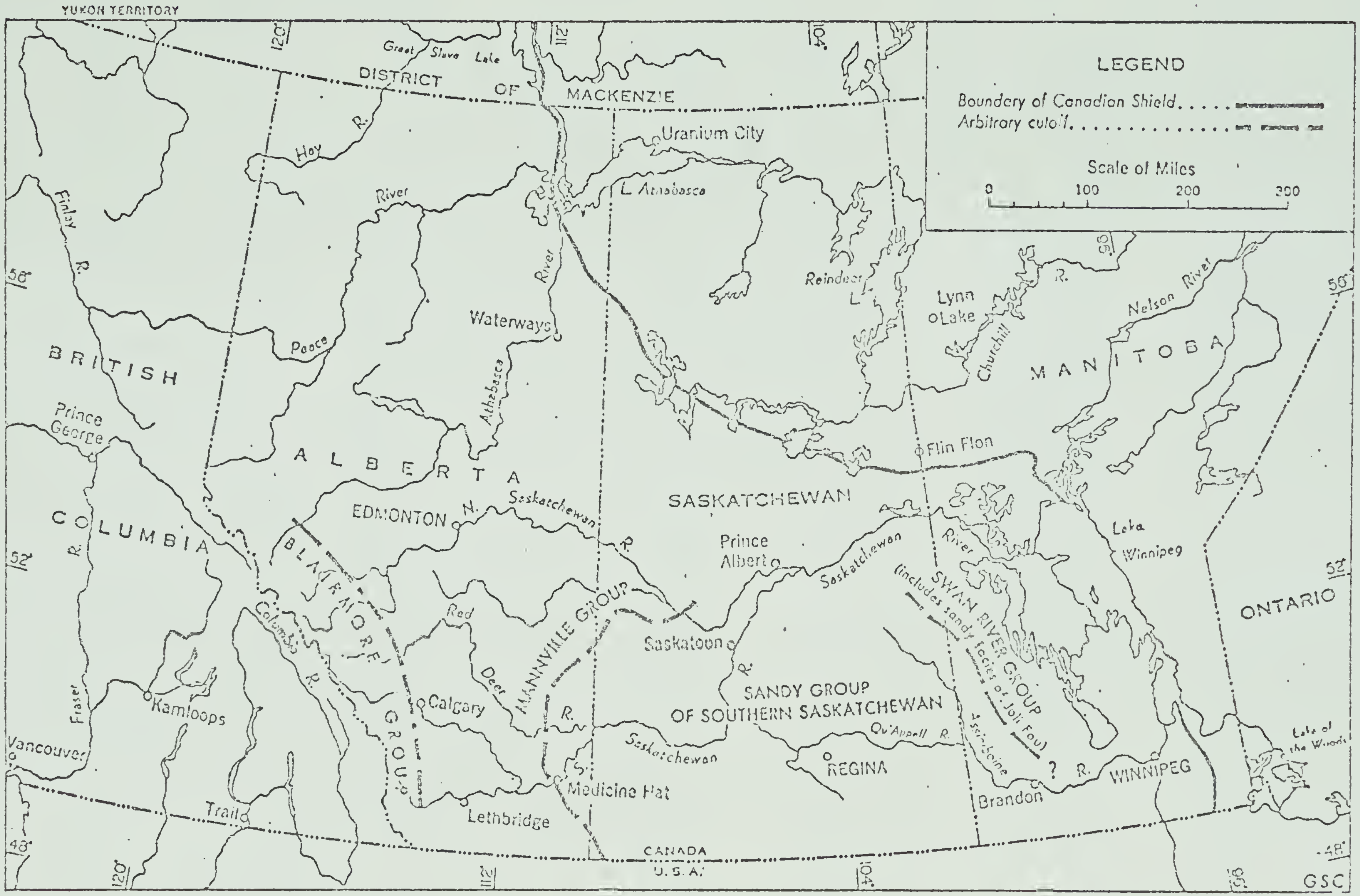


FIGURE: 3
PROBABLE GEOGRAPHIC LIMITS OF BASAL CRETACEOUS GROUPS OF THE CANADIAN PLAINS
(After Price, 1963)

of erosion. In the southern Alberta Foothills, the Lower Mannville is represented by the Lower Blairmore Formation. These rocks are predominantly non-marine. In the southern Alberta and adjacent Montana Plains, his Lower Mannville consists of, in ascending order, the Cutbank and Sunburst Sandstones and the "ostracod zone".

The Cutbank Sandstone (Blixt, 1941) lies unconformably on Jurassic shales and is correlated with the Taber Sandstone, Deville Member and the "Detrital Chert zone".

The Sunburst Sandstone is considered to be depositionally continuous with the upper part of the Cutbank Sandstone, both of which are correlated with the Ellerslie Formation in central Alberta.

Rudkin's (1964) "ostracod zone" is similar to that defined by Loranger (1951) which he considers to be a lithologic rather than biostratigraphic unit, as is its correlative, the "Calcareous" member of the southern Foothills.

Rudkin considers the Upper Mannville to represent a time of marine transgression over non-marine beds and so is a mixture of these two types of deposition. In the southern Alberta Foothills the Upper Mannville is represented by the Upper Blairmore Formation. These beds are essentially non-marine in the southern and central Plains and Foothills becoming intercalated with marine beds to the north and northeast, finally grading into entirely marine in the northern Plains and Foothills. Rudkin's (1964) Upper Mannville unit is the same as the Upper Mannville defined by Glaister (1959) and includes all the beds between the top of the "ostracod zone" or "Calcareous" member and the base of the Colorado Group.

The "Glauconitic sandstone" at the base is correlated with the Wabiskaw Member and the upper part of the Cummings Member in eastern and northeastern Alberta.

Mellon (1967) accepted Rudkin's (1964) twofold subdivision of the Mannville strata. He renamed Rudkin's (1964) Lower Mannville, the McMurray Formation, after Williams' (1960) definition of that unit and proposed the name Fort Augustus Formation for the Upper Mannville in the central Alberta Plains. Mellon (1967, pp. 63-64) considers the Fort Augustus Formation to be correlative with the type Clearwater and Grand Rapids Formations of the lower Athabasca River area but did not extend these names into central Alberta for the following reasons:

1. "In the central Plains the main break in the faunal succession of the Mannville Group coincides with the top of the McMurray Formation. In contrast, elements of the Clearwater microfaunal assemblage grade into strata assigned to the Grand Rapids Formation by Badgley (op. cit.) and Williams (op. cit.)."

2. "The main break in lithology and sandstone composition within the Mannville Group also coincides with the top of the McMurray Formation. In contrast, the Clearwater facies grades into the overlying Grand Rapids facies with no consistent break in lithology or sandstone composition. The use of an arbitrary electric log or lithologic datum to define the Clearwater-Grand Rapids boundary is impractical owing to the local lensing nature of the beds involved."

3. "The Clearwater-Grand Rapids contact is diachronous. The type Clearwater is composed mainly of shale that grades laterally into sandy beds towards central Alberta, as continental Luscar-type beds displace the marine

Grand Rapids sandstones in the upper part of the succession. Thus, Badgley's (op. cit.) and Williams' (op. cit.) Clearwater Formation in the Fort Augustus No. 1 well is composed mainly of marine (or littoral) sandstones that are lithologically and genetically similar to the Grand Rapids sandstones of the type outcrop area to the north."

Also in 1967, Maycock proposed a twofold subdivision for the Lower Cretaceous rocks in southwestern Saskatchewan. He called his lower unit the "Continental Facies" which he considered to be correlative to the type Cantuar Formation of Price (1963). He retained the name Pense Formation for his upper unit in the southern part of the study area. However, to the north of the Mississippian subcrop edge he considered the Mannville sediments to be undifferentiated.

The terminology used in this thesis is shown in Table 1.

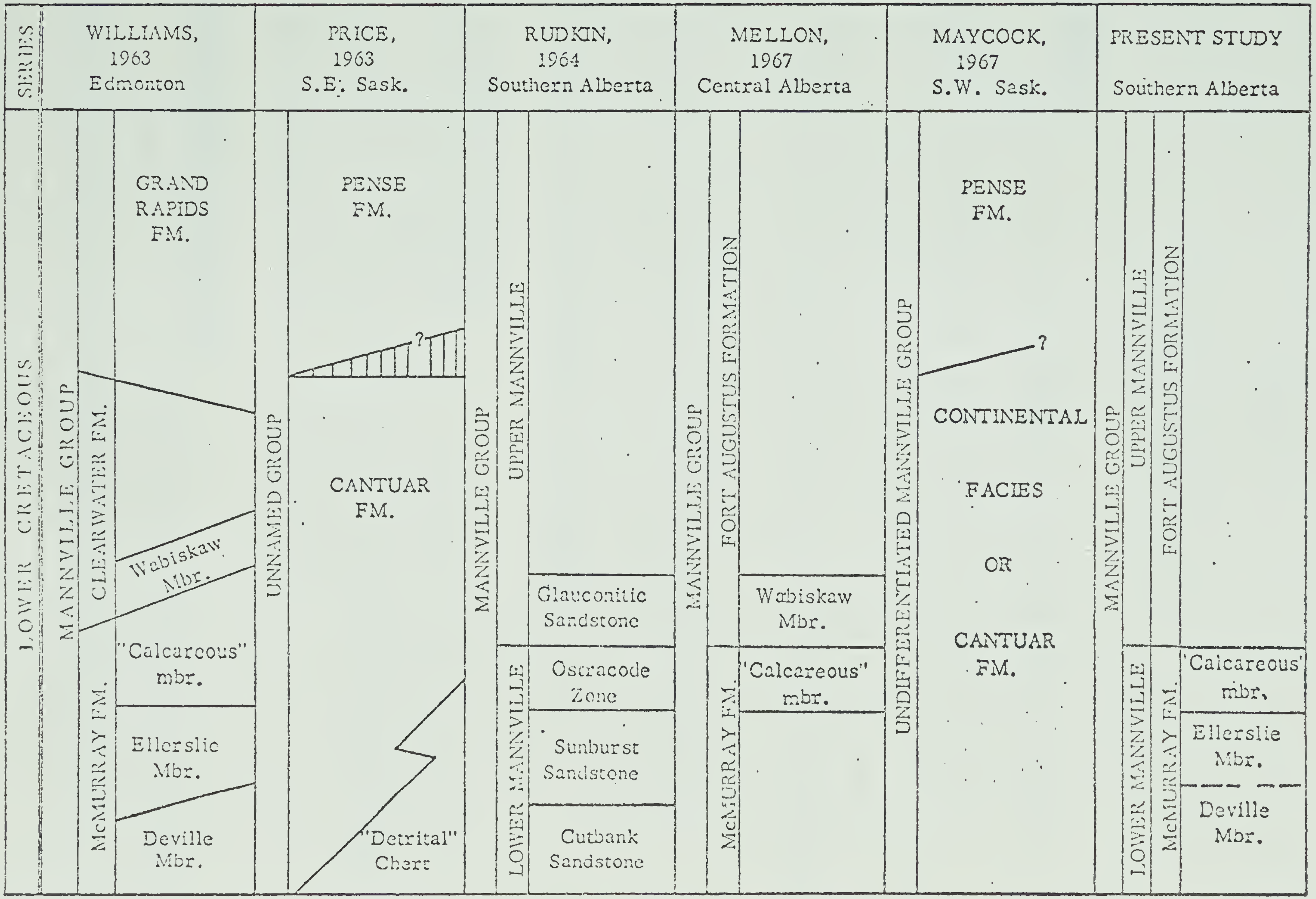


TABLE: 1

CORRELATION OF THE MANNVILLE GROUP

Chapter 2

PALEOGEOMORPHOLOGY

Introduction

Structure contour maps drawn from electric log data were prepared for the Base of Fish Scales marker (Figure 4) and for the Paleozoic surface (Figure 5) of the study area. In addition, an isopach map of the interval from the Base of the Fish Scales marker to the sub-Cretaceous unconformity (i.e. Lower Cretaceous) (Figure 6) was constructed to show the sub-Cretaceous surface with as much as possible of the westerly dip removed. Pre-Mannville paleogeology has been compiled from information and maps published by the Energy Resources Conservation Board of Alberta. Figures 4, 5 and 6 show the relationship of thickness changes to paleotopography.

Base of Fish Scales Structure

Structure contours on the Base of Fish Scales marker (top of Lower Cretaceous) show that this horizon dips to the west-northwest at approximately 20 feet per mile and the structure is relatively simple.

Paleotopography and Paleogeology

The complex isopach pattern in the study area (Figure 6) is due chiefly to erosional irregularities on the sub-Cretaceous unconformity inasmuch as the

upper limit of the mapped interval is relatively featureless (Figure 4). Tectonism has had a negligible effect on the isopach interval.

Most of the study area is underlain by the Mississippian Pekisko Formation which consists of dense, chalky and coarsely crinoidal limestone, siltstone and chert. East of Range 19, the sub-Cretaceous topography has been developed mainly on the Mississippian Banff Formation which consists of argillaceous limestone, chert, fine sandstone and dark shales.

Areas with thick isopach values indicate valleys or lows on the erosion surface while areas with thin values indicate ridges or high areas. Due allowance must be made for differential compaction that has occurred since deposition of the Fish Scales marker and for structural development that may have occurred while the isopached strata were being deposited.

The isopach pattern of Figure 6 has been interpreted as a series of subsequent valleys occupied by westerly flowing streams. The main valley, as shown by pronounced thickening of the isopached strata, may be traced from the southeastern part of the map area where it is closely related to the paleogeology, through Deadhorse Lake westward through Twp. 24, Rges. 19 and 20, through the vicinity of the "main" Hussar field from whence it extends in a westerly direction towards the edge of the map. A second fairly deep valley system is indicated in the vicinity of Twps. 25 and 26, Rge. 22, W4M where it extends to the west probably joining the main valley system towards the edge of the map area in Twp. 25, Rge. 24, W4M. Several tributaries enter into these valleys which drain the map area. The gradient of the main valley is approximately $4\frac{1}{2}$ feet per mile, with no evidence of tectonism in the study area based on the regularity of the contour patterns.

Chapter 3

STRATIGRAPHY

Introduction

The lower limit of the Mannville Group is placed at the post-Paleozoic erosional surface and the upper limit at the base of the overlying black marine shales of the Joli Fou Formation. The Mannville Group has been divided into lower and upper units similar to those defined by Rudkin (1964) and Mellon (1967) (see Table 1). The Mannville Group ranges in thickness from 450 feet to 650 feet in the study area, the main differences being attributed to topographic irregularities on the underlying unconformity.

With the cored intervals in the nine study wells as control (Figure 2) lithologic boundaries were determined in the remaining wells in the study area by using electric log profiles. Figures 7, 8 and 9 are stratigraphic cross-sections based chiefly on core examination and electric log profiles. By combining the maps with the information on the stratigraphic cross-sections, facies changes may be related to the underlying erosional topography.

McMurray Formation

The McMurray Formation includes all the strata between the sub-Cretaceous unconformity and the top of the "Calcareous" member. The formation in the Hussar area consists of a lower zone of residual light greyish to bluish

green waxy shale, the Deville Member (Badgley, 1952), a middle quartz sandstone facies, the Ellerslie Member (Hunt, 1950) and an upper calcareous shale facies, the "Calcareous" member (Glaister, 1959). The top of the McMurray is usually easily recognizable and provides a useful marker in the study area.

Deville Member. The name Deville was originally suggested by Badgley (1952) for the zone of erosion detritus which occurs between 3,555.5 feet and 3605 feet in the Imperial Deville No. 1 well (Lsd. 9, Sec. 36, Twp. 51, Rge. 20, W4M). This member is described by Badgley (1952, p.7) as consisting of "... greenish grey, waxy shales; greyish green, argillaceous, quartzose sandstones; and dark reddish brown shales and silty shales. Siderite nodules are commonly embedded in the shales."

The Deville Member has been encountered in cores of wells examined in the study area and the contact with the overlying Ellerslie Member was found to be gradational except in Tenn Ar 1 Hussar No. 14-7 (Lsd. 14, Sec. 7, Twp. 26, Rge. 21, W4M) and CPOG Hussar No. 10-12 (Lsd. 10, Sec. 12, Twp. 25, Rge. 20, W4M) both of which contain distinct contacts.

In cores which were examined, the member is composed of light greyish to bluish green, waxy, sandy, pyritic shale and shaly siltstones with angular to rounded quartz and chert fragments, and very fine to medium grained sandstones. It is highly brecciated and slickensided in places.

The Deville Member is sporadically distributed and is mainly restricted to low areas on the sub-Cretaceous surface.

Ellerslie Member. The name Ellerslie, was proposed by Hunt (1950) for

the "Quartz Sand Series" (Layer, 1949) of the Edmonton area. The type section was chosen in the Imperial Whitemud No. 3 well (Lsd. 12, Sec. 14, Twp. 51, Rge. 25, W4M). According to Hunt (1950, p. 1799), "... the top of the Ellerslie ("Quartz Sand series") is determined by the first occurrence of vitreous pure-quartz sand or silt below the 'Ostracod zone'."

In the type area, this member consists of a lower zone "...of angular and medium-grained quartz sands, carbonaceous silty shales, varved quartz silts and silty shales, and traces of coal "and an upper zone "...of sand inter-lensed with thinly cross-bedded gray sandy shales and shaly sands. The sands are fine to very fine-grained, firm to friable and fossiliferous" (Hunt, 1950, p. 1799).

The above criteria were used to define the Ellerslie Member in cores of the wells studied. In cores which were examined the upper contact was found to be gradational.

Within the study area sandstones predominate but interbeds of siltstones and shales are not uncommon. The sandstones are yellowish grey to light olive grey, fine to medium grained, moderately well sorted, subangular to subrounded quartz type but "salt and pepper" varieties are also present in minor amounts. Locally the sandstones are micaceous, calcareous, sideritic, friable and lightly oil stained in places and porosity is generally fair. The siltstones and shales are mainly light grey to greenish grey, often carbonaceous, pyritic, micro-micaceous and thinly laminated.

The Ellerslie Member was found to be petrographically similar to the Deville Member and occupying low areas on the sub-Cretaceous surface (see Figures 7, 8 and 9).

"Calcareous" member. The name "Calcareous" member, was applied by Glaister (1959, p. 605) to "... a rock unit which closely coincides with Metacypris persulcata zone, more commonly known as the "Ostracod zone" described by Loranger (1951). The "Calcareous" member, however, is a lithologic unit, not a biostratigraphic unit, and can be correlated beyond the areal extent of the zone fossil." The name Metacypris angularis zone, was applied to this member by Badgley (1952, p.9) who described it as consisting "... dominantly of dark grey shales, which are fossiliferous, thinly laminated, fissile to platy, generally calcareous, commonly pyritic and locally silty."

The upper contact is distinct in the cores examined and the characteristics of the accompanying well logs were then utilized to determine this marker horizon in the remaining wells of the study area.

The "Calcareous" member consists of olive grey to dark grey calcareous shale, silty shale which commonly grades into siltstone, argillaceous olive grey limestones and thin calcareous sandstone. Gastropods, pelecypods, ostracods and fish remains are common in the unit and sandstone lentils are present at the base of the "Calcareous" member. These "salt and pepper" sandstones are fine to very fine grained, fair to poorly consolidated, subangular to subrounded, porous and permeable in the Hussar field. The lentils occupy a stratigraphic position similar to those sand bodies described by Williams (1960) in the Big

Lake and Alexander gas fields. The name "Ostracod sandstone" is currently used by the oil industry for these lentils.

Fort Augustus Formation

The Fort Augustus Formation includes the stratigraphic interval from the top of the "Calcareous" member to the base of the overlying Joli Fou Formation. This interval consists of a lower unit of dark grey shales, siltstones and"salt and pepper"sandstones. This unit interfingers with an upper unit of medium grey silty carbonaceous shale and coal with minor"salt and pepper" sandstones. The uppermost limit of the Mannville is placed at the top of the first siltstone or sandstone bed below the marine Joli Fou shales of the Colorado Group.

Faunal and Floral Elements

Megafossils were collected from the cores of five of the study wells. The cores from the remaining four wells were non-fossiliferous. Depth and identification of specimens collected are listed in Appendix D.

Pelecypods, gastropods, ostracods and plants constitute the main fossils collected from the Mannville strata in the study wells.

Cores from the Deville Member were non-fossiliferous, Ellerslie and Fort Augustus cores contained mainly plants, while faunal elements were relatively abundant in the "Calcareous" member. The following is a composite list of the forms identified:

I. Fauna

A. Pelecypods:

Astarte? sp.

Astarte natosini McLearn

Corbula sp., cf. *C. palliseri* McLearn

Corbula fragments

Elliptio sp.

Pelecypod fragments

Pelecypod indeterminate

Sphaerium sp.

Tancredia sp.

Unio sp.

B. Gastropods:

Lioplacodes sp., cf. *L. bituminis* Russell

Planorbis sp.

Scalez sp.

C. Arthropods:

Ostracods

D. Miscellaneous:

Fish fragments

II. Flora

Athrotaxopis sp.

Ptilophyllum montanense (Fontaine)

Zamites sp.

Conifer needles

Plant remains indet.

Correlation and Stratigraphic Interpretation

Lithologic criteria including petrographic evidence, electric well log profiles and evidence from X-ray fluorescence analysis were used for correlation. In many cases it was difficult to determine accurately the contacts between individual formations and members because of the gradational nature of most contacts. Correlation is also rendered very difficult by the lenticular nature of the sandstones.

Chapter 4

PETROGRAPHY OF THE SANDSTONES

Sample Locations and Preparation

Fifty-six thin sections representing lithologies from the McMurray and Fort Augustus Formations were prepared. The thin sections were left uncovered and were subjected to the feldspar staining technique described by Bailey and Stevens (1960) in which potassium feldspar is stained yellow using sodium cobaltinitrite. Stratigraphic distribution of the thin sections is as follows:

Fort Augustus Formation	25 thin sections
McMurray Formation	31 thin sections

Samples were evenly distributed throughout the McMurray Formation but were restricted to the lower part of the Fort Augustus Formation because, as mentioned earlier, coring was begun too low in the section to give a good sampling of the Fort Augustus Formation. Depth of each sample is given in Appendix A.

Techniques

The point count method (Chayes, 1954) was used to analyse twenty-five thin sections, thirteen from the McMurray Formation and twelve from the Fort Augustus Formation. Two hundred grains per thin section were identified and classified as quartz, rock fragments or feldspar. Matrix and cement together

accounted for an additional fifty to one hundred and fifty points. Quartz was further subdivided into slightly undulatory, undulatory, polycrystalline and sedimentary (rounded to well rounded grains) varieties. Rock fragments were subdivided into microcrystalline chert, coarse crystalline chert (> 0.1 mm.dia.), metamorphic, sedimentary and volcanic rock fragments. Cement was identified as silica, carbonate or iron oxide.

General Description of Thin Sections

Structures are not apparent for the most part, however a few thin sections show stratification by alignment of elongate grains or concentration of finer material.

Sandstones in the Deville and Ellerslie Members are difficult to differentiate petrographically. Grain size varies from very fine to very coarse grained sand with most of the samples being in the very fine to fine grained range. Grain roundness ranges from angular to well rounded, and sorting from poor to well sorted. Grains are normally packed and detrital contacts (Siever, 1959) range from tangential to sutured, with tangential inter-grain contacts being the more common.

Sandstones in the "Calcareous" member are very fine to coarse grained with most of the samples being fine grained sand. Grain roundness ranges from angular to subrounded and sorting is fair. Grains are generally closely packed and detrital contacts are mainly straight. In one thin section examined from the Leduc Consolidated Socony Chancellor No. 3 well (Lsd. 2, Sec. 24, Twp. 25,

Rge. 21, W4M), grain size varies from very fine to very coarse sand. Roundness of grains varies from subangular to well rounded and sorting is poor.

Most of the Fort Augustus sandstones consist of very fine grained sand, although the total size range encompasses coarse silt to medium grained sand. Most of the grains are subrounded to angular, are generally closely packed and the sandstones are fair to poorly sorted.

Globules and fine micaceous and opaque dust are the common inclusions in the quartz grains. Inclusions of quartz, mica and zircon as well as aligned acicular crystals of unknown composition were also observed in some samples.

Small amounts of mica and chlorite were found in a few thin sections from the Fort Augustus Formation. Pyrite, siderite and carbonaceous opaques were also noted in variable small amounts.

Essential Components

Essential components are mineral constituents which are considered necessary to the classification of the sandstone; in this case, quartz, rock fragments and feldspars. The averages for the essential components of McMurray sandstones when calculated to 100 percent are: 79 percent quartz, 21 percent rock fragments and less than 1 percent feldspar. For the Fort Augustus Formation the figures are 49 percent quartz, 41 percent rock fragments and 10 percent feldspar.

Quartz. Detrital quartz has frequently been subdivided into several genetic types on the basis of external and internal morphology, type of

inclusions and extinction characteristics (Krynine, 1948; Folk, 1964). Work by Blatt and Christie (1963) and Conolly (1965) has cast strong doubt on the validity of this approach. In the present study, no attempt was made to distinguish genetic groups, but a survey was made of the percentage of slightly undulatory quartz, undulatory quartz, polycrystalline quartz and sedimentary quartz, varieties which can be distinguished on the basis of objective criteria.

The most common type of detrital quartz consists of grains with undulatory extinction. These are probably derived from igneous, metamorphic and sedimentary rocks but lack of definitive characteristics makes it difficult to assign them to a particular source. Blatt and Christie (1963) concluded that no real difference exists in the degree of undulatory extinction in quartz from igneous and metamorphic rocks.

Non-undulatory quartz, if restricted to Blatt and Christie's (1963) definition, makes up a very small percentage of the samples. If Folk's (1964) definition for slightly undulatory quartz is used (complete extinction with less than 5 degrees stage rotation), then for the McMurray Formation, slightly undulatory quartz makes up from 10 to 53 (average 26) percent and undulatory quartz from 21 to 49 (average 33) percent of the framework. For the Fort Augustus Formation, slightly undulatory quartz composes from 9 to 45 (average 29) percent and undulatory quartz from 20 to 56 (average 29) percent of the framework.

Polycrystalline quartz grains consist of two or more quartz crystal units showing slightly to strongly undulatory extinction. Aggregate grains of common quartz sometimes called "composite quartz" (Folk, 1964) were arbitrarily included in this group. Medium sized polycrystalline quartz composed of ten or more quartz crystal units is thought to be an excellent indicator of a metamorphic source (Blatt and Christie, 1963). Medium sized quartz grains composed of less than five individual quartz crystals are thought to be derived from granites and schists (Blatt and Christie, 1963). The former variety is common in the thin sections examined. Polycrystalline quartz varies from 3 to 43 (average 24) percent in McMurray sandstones. In the Fort Augustus Formation, polycrystalline quartz makes up from 8 to 63 (average 41) percent of the framework.

Rounded to well rounded quartz grains have been classified as sedimentary quartz. These grains have probably undergone several cycles of erosion. Reworked sedimentary quartz grains with authigenic quartz over-growths are common in sandstones of the McMurray Formation. Sedimentary quartz constitutes 3 to 26 (average 18) percent of McMurray sandstones. In the Fort Augustus Formation sedimentary quartz makes up less than 3 (average 1) percent of the framework fraction.

Rock fragments. Rock fragments constitute as little as 5 percent of the framework in the McMurray Formation to 66 percent in the Fort Augustus Formation. Microcrystalline chert is the most abundant type in all thin sections examined. Colored (pale brown) chert and a few grains of chalcedonic chert

SAMPLE NO.	HPH-10	CH-5	CSC-10	CSC-12	CSC-13	CSC-14	CSC-15	CSC-16	HPH-6	HPH-7	HPH-9	HPW-4	CSC-5
Slight undulatory quartz	14.8	17.5	33.8	15.5	8.5	3.3	6.0	8.3	9.6	28.0	19.8	16.1	28.4
Undulatory quartz	33.8	32.9	17.6	11.4	6.9	8.3	12.5	11.9	26.8	28.7	30.6	21.7	25.8
Polycrystalline quartz	11.0	16.7	2.0	12.2	7.9	14.5	11.3	21.9	18.0	23.3	7.1	14.5	16.3
Sedimentary quartz	9.5	7.9	10.1	13.5	7.5	7.3	12.0	14.6	16.8	3.0	18.7	5.9	1.9
TOTAL QUARTZ	69.1	75.0	63.5	52.6	30.8	33.4	41.8	56.7	71.2	83.0	76.2	58.2	72.4
Microcrystalline Chert	1.9	2.1	4.7	20.8	19.2	14.5	9.5	20.6	5.2	1.0	1.2	5.3	4.5
Coarse crystalline chert (> 0.1 mm dia.)	2.3	4.2	9.5	6.1	14.8	10.2	6.2	6.0	2.4	1.7	0.8	1.6	1.9
Meta. volc. and sed. rock fragments	2.7	2.1		2.0	4.4	5.5	5.3	0.7	2.0	2.0	2.0	0.7	0.8
TOTAL ROCK FRAGMENTS	6.9	8.4	14.2	28.9	38.4	30.2	21.0	27.3	9.6	4.7	4.0	7.6	7.2
K-FELDSPAR		0.4								0.3			1.1
Matrix	20.6	7.1	10.1	4.2	22.0	31.2	26.2	5.0	6.0	1.3	5.9	10.8	4.5
Cement	3.4	9.1	12.2	14.3	8.8	5.2	11.0	11.0	13.2	10.7	13.9	23.4	14.8
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Recalculation for Classification													
Quartz	90.9	89.5	81.7	64.5	44.5	52.5	66.6	67.5	88.1	94.3	95.0	88.4	89.7
Rock Fragments	9.1	10.0	18.3	35.5	55.5	47.5	33.4	32.5	18.9	5.3	5.0	11.6	8.9
Feldspar		0.5								0.4			1.4
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 2-I Composition of Lower Mannville Sandstones (Volume Percent)

Sample No.	HPH-3	HPH-4	CHH-2	CHH-3	HPH-2	MCP-2	CH-1	HFW-1	HPW-2	CSC-2	CSC-4	SWH-1
Slightly Undulatory quartz	16.0	24.3	10.6	15.2	6.3	7.2	11.1	4.3	7.3	6.8	3.9	12.1
Undulatory quartz	30.3	39.7	4.8	11.0	9.2	11.4	5.8	11.9	4.8	4.9	5.8	8.5
Polycrystalline quartz	15.7	6.0	8.2	16.7	16.5	26.9	12.1	28.6	10.9	6.0	15.2	9.1
Sedimentary quartz	2.0	1.0			0.7	0.9		0.6	0.6	0.5	0.2	0.3
TOTAL QUARTZ	64.0	71.0	23.6	42.9	32.7	46.4	29.0	45.4	23.6	18.2	25.1	30.0
Microcrystalline Chert	7.7	6.7			13.9	13.2		6.1	10.6	13.4	5.5	6.2
Coarse crystalline Chert (>0.1 mm dia.)	8.7	4.7			3.9	15.3		11.2	2.1	5.4	4.3	5.5
Meta, volc. and sed. rock fragments	4.0	3.0			10.9	3.9		5.5	14.2	9.6	12.3	16.9
TOTAL ROCK FRAGMENTS	20.4	14.4	65.9	37.1	28.7	32.4	54.6	22.8	26.9	28.4	22.1	28.6
K-FELDSPAR	1.3	0.6	10.5	20.0	4.9	4.5	16.4	8.2	10.0	8.2	6.3	6.5
Matrix	4.0	3.3			20.8	11.1		13.9	22.3	26.6	27.6	19.5
Cement	10.3	10.7			12.9	5.6		9.7	17.2	18.6	18.9	15.4
TOTAL	100.01	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Recalculation for Classification												
Quartz	74.7	82.6	23.6	42.9	49.3	55.7	29.0	59.4	39.0	33.2	46.9	46.0
Rock Fragments	23.8	16.7	65.9	37.1	43.2	38.9	54.6	29.8	44.5	51.8	41.3	43.9
Feldspar	1.5	0.7	10.5	20.0	7.5	5.4	16.4	10.8	16.5	15.0	11.8	10.1
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 2-II Composition of Upper Mannville Sandstones (Volume percent)

were observed in some of the samples. Microcrystalline chert is usually slightly larger and more angular than the quartz grains and is usually elongate.

Low grade metamorphic rock fragments characterized by the presence of biotite and chlorite were noted in minor amounts.

Volcanic rock fragments were noted in very minor amounts in thin sections from the Fort Augustus Formation but are difficult to differentiate from argillaceous rock fragments.

Feldspar. Potassium feldspar is the most common variety observed, ranging from less than one percent in McMurray sandstones to 20 percent in the Fort Augustus Formation. Plagioclase is present in very minor amounts.

Matrix

Matrix is defined as that component of the rock with an average grain diameter less than one-tenth that of the framework fraction. Matrix is composed of clay, silt, mica, feldspar and quartz. It is usually difficult to distinguish matrix from badly deformed sedimentary rock fragments, and in some cases matrix may have been replaced by carbonate cement.

Cement

The most abundant cement is silica which occurs as authigenic overgrowths in optical continuity with detrital quartz grains. Quartz overgrowths were distinguished from the detrital nucleus by one or more of the following criteria (Lerbekmo, 1961): the nucleus has inclusions while the overgrowth has relatively few or none; a thin line of impurities marks the boundary between

the detrital grain and the authigenic overgrowth; the detrital grain shows straining or undulatory extinction whereas the overgrowth does not.

Calcite cement is present in variable amounts replacing quartz grains, silica cement and matrix. Replacement of the grains proceeds from the outer edge of the grains inward, advantage being taken of existing cracks and cavities.

Iron oxide cement was also noted in a few samples.

Porosity

Pore space was excluded from the point count because in many cases porosity could not be distinguished from holes produced in making the thin section. Porosity appears to be as high as 20 percent in some of the samples, but commonly is much less.

Classification

The compositional classification of sandstones proposed by Travis (1955) has been adopted in the present study. This includes chert with rock fragments, thus is slightly different from most contemporary classifications.

Figure 10 shows the proportions of essential components recalculated to 100 percent for each sample. Sandstones of the McMurray Formation are notably low in feldspar and show wide variations in rock fragment content, indicating reworking of the detritus and local secondary sources particularly in the lower beds (Williams, 1960). According to the Travis classification

the McMurray Formation is composed of quartz sandstones and lithic sandstones with one exception.

Sandstones of the Fort Augustus Formation are noticeably richer in rock fragments and feldspar and their composition is more variable. Texturally, these sandstones are much less mature than those of the McMurray. According to the Travis classification, nine of the twelve samples are lithic sandstones, whereas the remaining three are rock fragment sandstones.

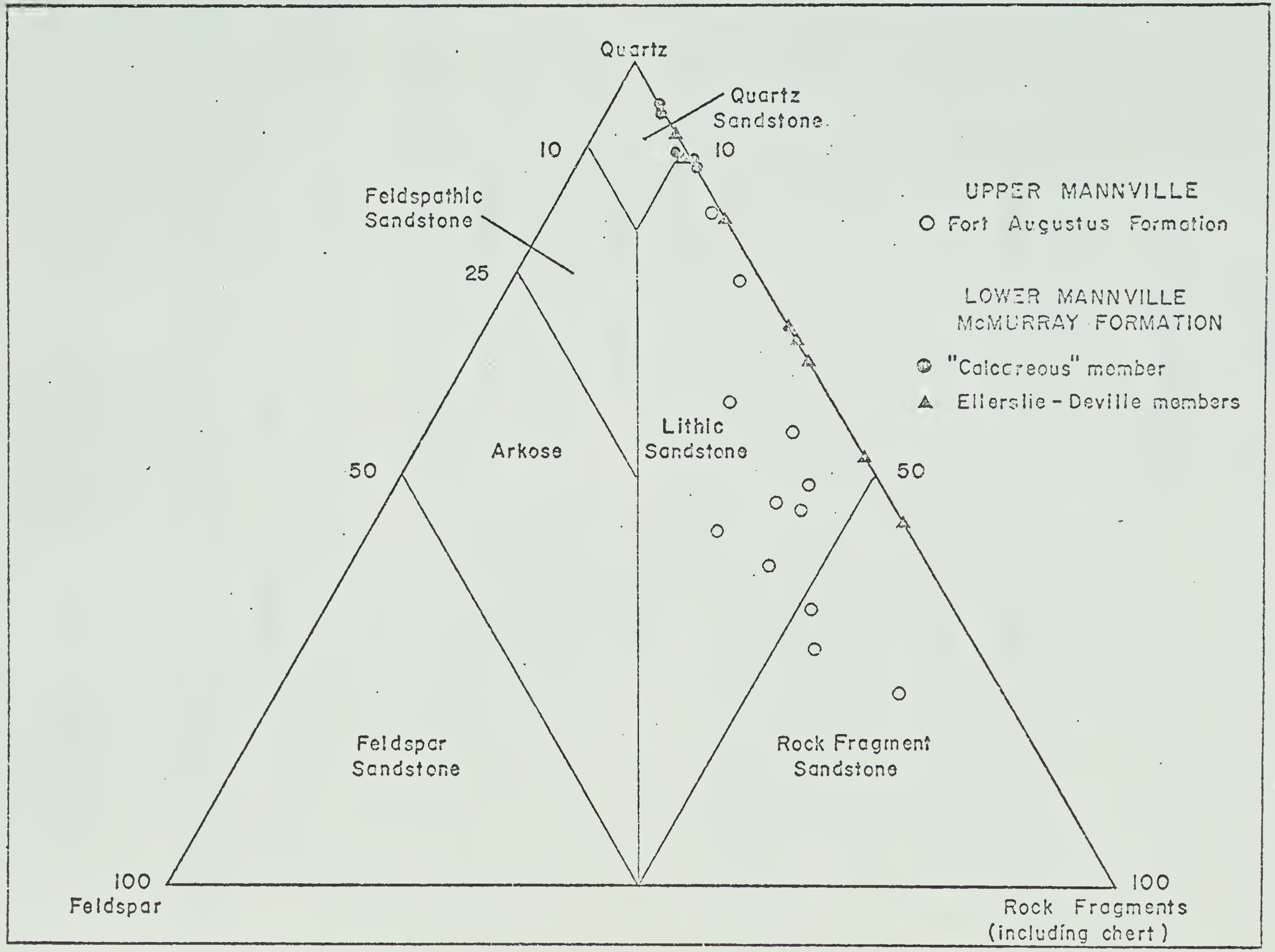


FIGURE:10. Compositional Classification of Sandstones in the Mannville Group. (triangular diagram after Travis, 1955)

Chapter 5

GEOCHEMISTRY

Sample Locations and Preparation

Seventy-five shale samples were selected at different stratigraphic intervals from seven of the nine study wells for X-ray fluorescence analysis. The sample for analysis consisted of a measured volume, approximately one gram in weight, of finely ground pure shale pressed into a briquet with a cellulose backing at a pressure of 30,000 p.s.i. Stratigraphic distribution of the shale samples from the seven wells is as follows:

Joli Fou Formation	4 samples
Fort Augustus Formation	41 samples
McMurray Formation	30 samples.

Depth of each sample is given in Appendix A.

Techniques

The primary purpose of this phase of the investigation has been to establish chemical variations which might be of value for correlation purposes. Eight elements were investigated: Si, Mg, Al, K, Ca, Fe, Sr and Rb.

Analytical determinations were made on a Phillips Norelco Type 12215/0 unit, employing chromium radiation for all elements except iron, strontium and rubidium, for which a molybdenum source was used. For elements

below iron in the periodic table, the analyses were conducted in a vacuum of 0.5 mm. of mercury or less, and pulse height discrimination was employed to limit interference.

Operating procedure involved placing three unknowns and one analyzed standard in the sample holder for each analysis. Continued use of the running standard provided a check on possible instrument drift as well as a medium for calculating the precision of repeat determinations. The total count on the $K_{\alpha 1}$ peak for each element was obtained for fixed periods of time. The same count determination was made at background position and the count above background for the element determined by difference of the two counting rates. Chemically analyzed shale standards were used to set up calibration curves for conversion of counting rates to weight percent for each element. The major elements have been reported as oxides.

Generally, it was found that the working curves derived from analyzed standards were smooth and relatively linear for most of the elements. Calibration curves for X-ray fluorescence determinations, chemical analyses of standards and typical fluorescence operating conditions are given in Appendix E.

Distribution of Major Constituents

The results of the major constituent analysis are shown graphically in Figures 11-I through 11-VII. The averages for the various formations or members are given in Table 3-1 and the composition of shales from Imperial Sprucefield No. 1 (Lsd. 1, Sec. 31, Twp. 60, Rge. 19, W4M) (Campbell and

Table 3-I

Major Chemical Constituents of Shales *
(Weight Percent)

	SiO_2	MgO	Al_2O_3	K_2O	CaO	Fe_2O_3	Total
Joli Fou Fm.	53.2	1.72	18.49	2.50	0.55	4.80	81.26 **
	(64.7)	(2.27)	(19.94)	(2.22)	(0.43)	(5.63)	(95.19)
Mannville Gp.							
Ft. Augustus Fm.	57.6	1.07	19.62	1.83	0.28	2.73	84.13 **
(Grand Rapids Fm.)	(62.8)	(2.29)	(15.37)	(2.43)	(2.95)	(6.05)	(91.89)
(Clearwater Fm.)	(64.7)	(2.78)	(16.51)	(2.91)	(1.13)	(5.63)	(93.66)
McMurray Fm.							
"Calcareous" mbr.	54.3	1.04	19.27	1.73	1.83	2.93	81.10 **
	(71.8)	(1.00)	(16.25)	(0.94)	(1.64)	(1.35)	(92.98)
Ellerslie-Deville							
Mbrs.	54.4	0.47	23.01	0.89	0.29	1.75	80.81 **
(Ellerslie Mbr.)	(73.3)	(1.73)	(13.03)	(1.37)	(1.52)	(0.80)	(91.75)

* Bracketed values are from Campbell and Williams (1965), p. 82.

** Excluding Na_2O.

Table 3-II

Minor Constituents and Significant Ratios *

	Sr (ppm)	% Ca	Sr/Ca	Rb(ppm)	% K	Rb/K
Joli Fou Fm.	200	0.39	0.051	144	2.07	0.0069
	(220)	(0.31)	(0.071)	(126)	(1.85)	(0.0068)
Mannville Gp.						
Ft. Augustus Fm.	153	0.20	0.076	177	2.35	0.0075
(Grand Rapids Fm.)	(227)	(2.11)	(0.011)	(87)	(2.02)	(0.0043)
(Clearwater Fm.)	(200)	(0.81)	(0.025)	(124)	(2.41)	(0.0051)
McMurray Fm.						
"Calcareous" mbr.	268	1.31	0.025	97	1.44	0.0067
	(316)	(0.99)	(0.032)	(36)	(0.78)	(0.0046)
Ellerslie-Deville Mbrs.	99	0.21	0.047	41	0.73	0.0056
(Ellerslie Mbr.)	(109)	(1.08)	(0.010)	(36)	(1.13)	(0.0032)

* Bracketed values are from Campbell and Williams (1965), p. 84.

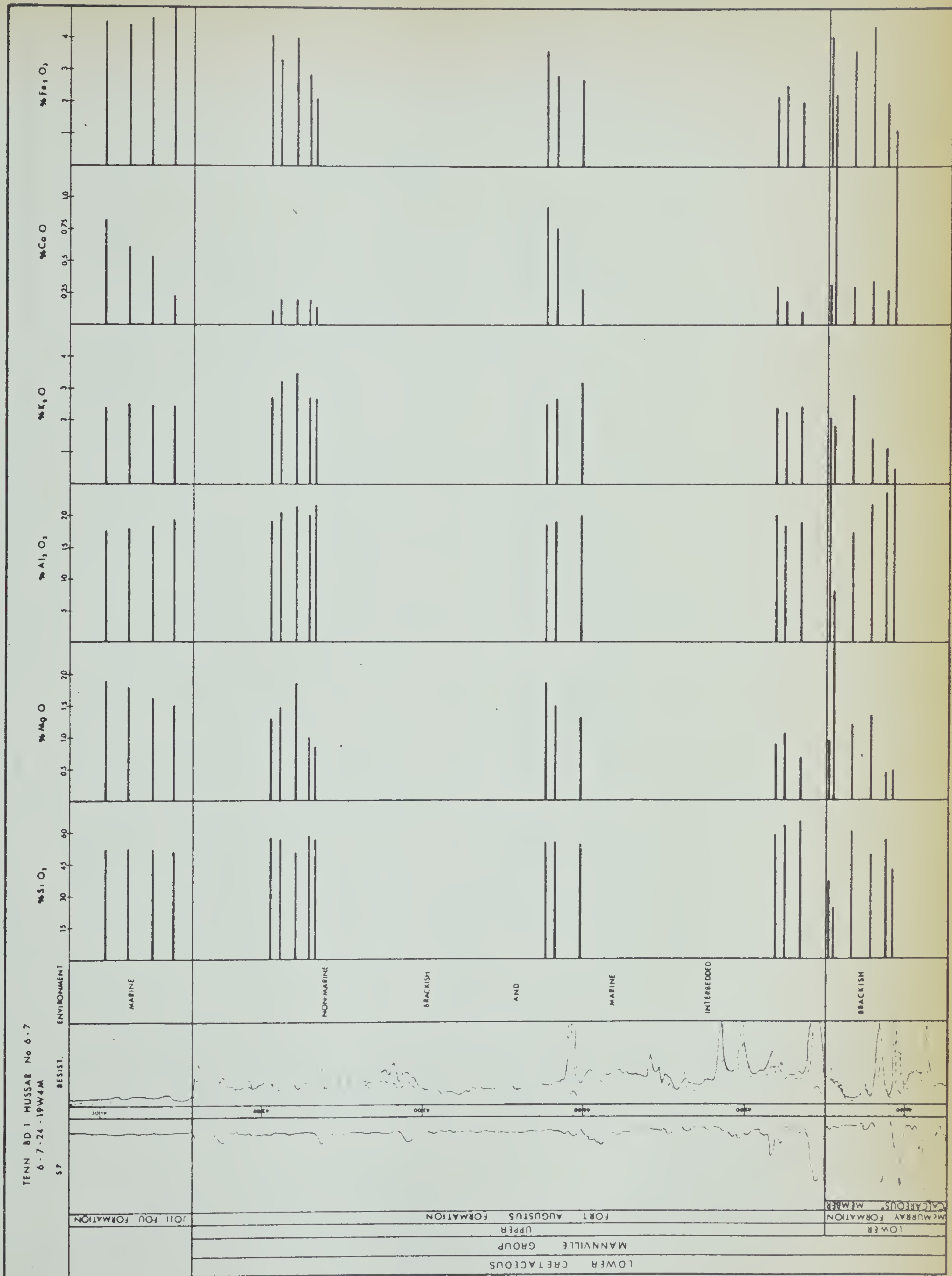
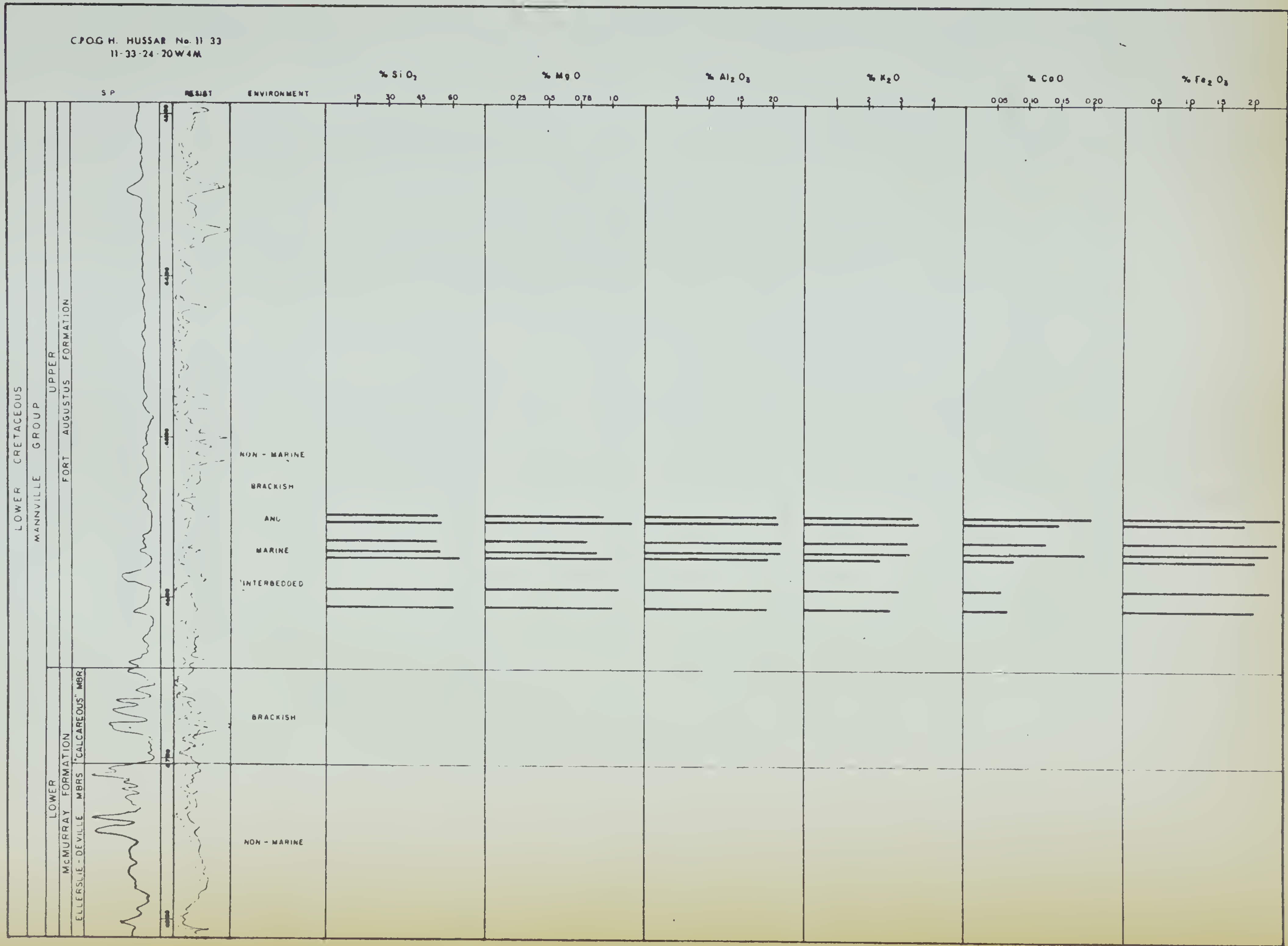

TENN BD I HUSSAR No 6-7
6-7-24-19W4M
SP
RESIST.
ENVIRONMENT
MARINE
NON-MARINE
BRACKISH
AND
MARINE
INTERBEDDED
BRACKISH
%SiO2
%MgO
%Al2O3
%K2O
%CaO
%Fe2O3
JOLI FOU FORMATION
FORT AUGUSTUS FORMATION
McMURRAY FORMATION
"CALCAREOUS" MEMBER
UPPER
LOWER
MANNVILLE GROUP
LOWER CRETACEOUS

FIGURE II-1



C.P.O.G. H. HUSSAR No. 11 33
11-33-24-20W4M
SP
RESIST
ENVIRONMENT
% SiO2
15 30 45 60
% MgO
0.25 0.5 0.78 1.0
% Al2O3
5 10 15 20
% K2O
1 2 3 4
% CaO
0.05 0.10 0.15 0.20
% Fe2O3
0.5 1.0 1.5 2.0
NON - MARINE
BRACKISH
AND
MARINE
INTERBEDDED
BRACKISH
NON - MARINE
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
FORT AUGUSTUS FORMATION
LOWER
McMURRAY FORMATION
ELLERSLIE - DEVILLE MBRS
"CALCAREOUS" MBR.

FIGURE II-11

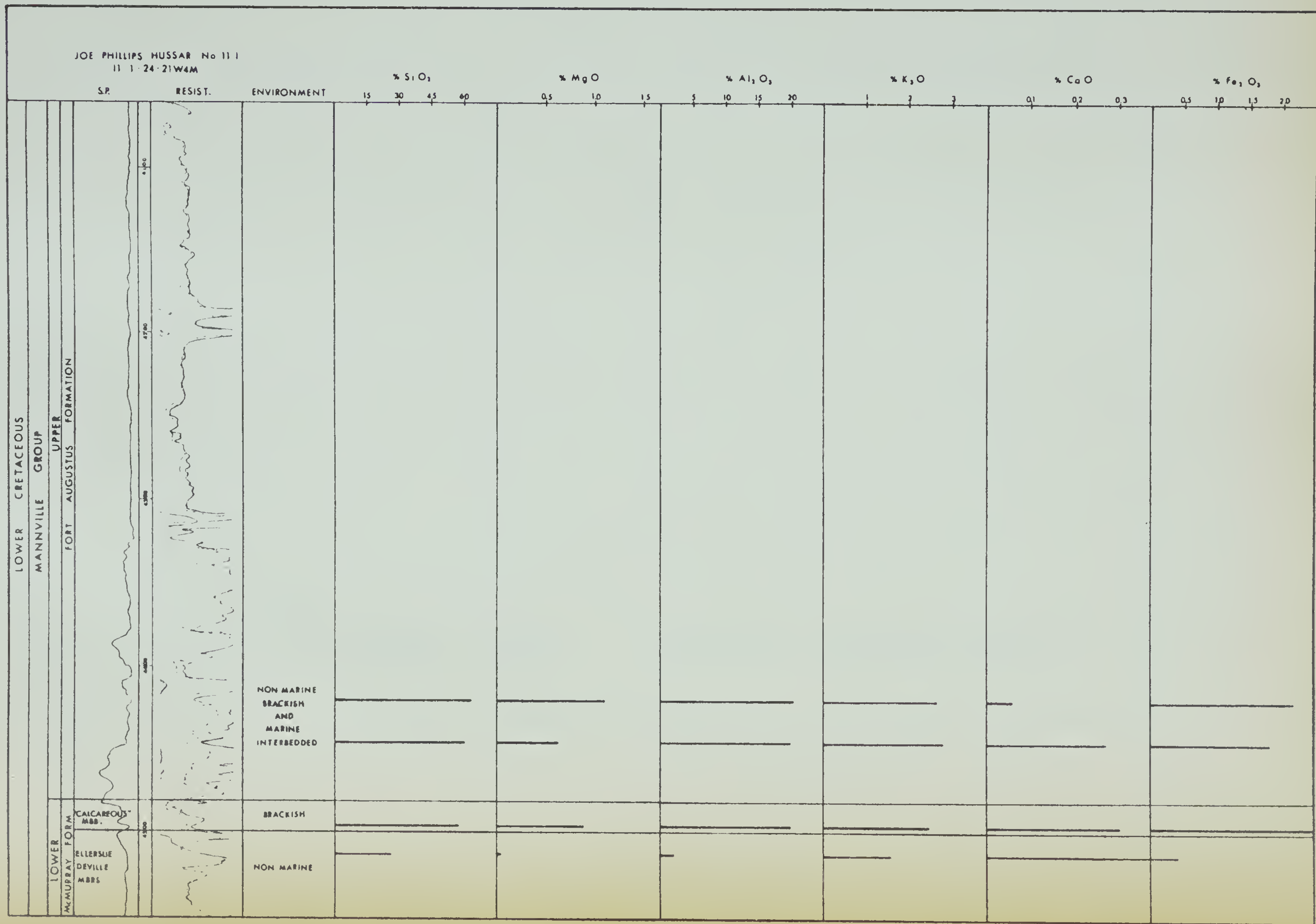


FIGURE II-III

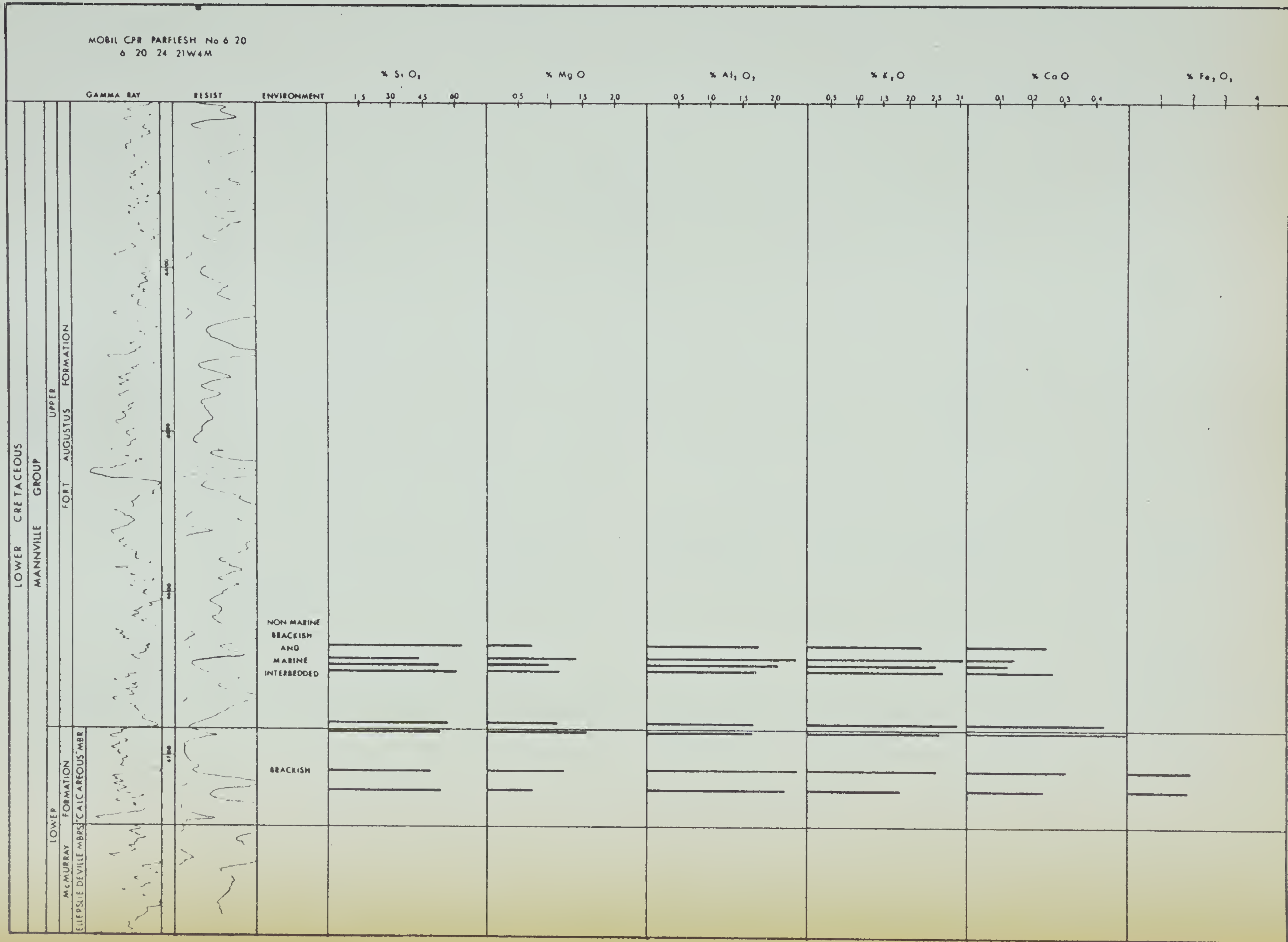
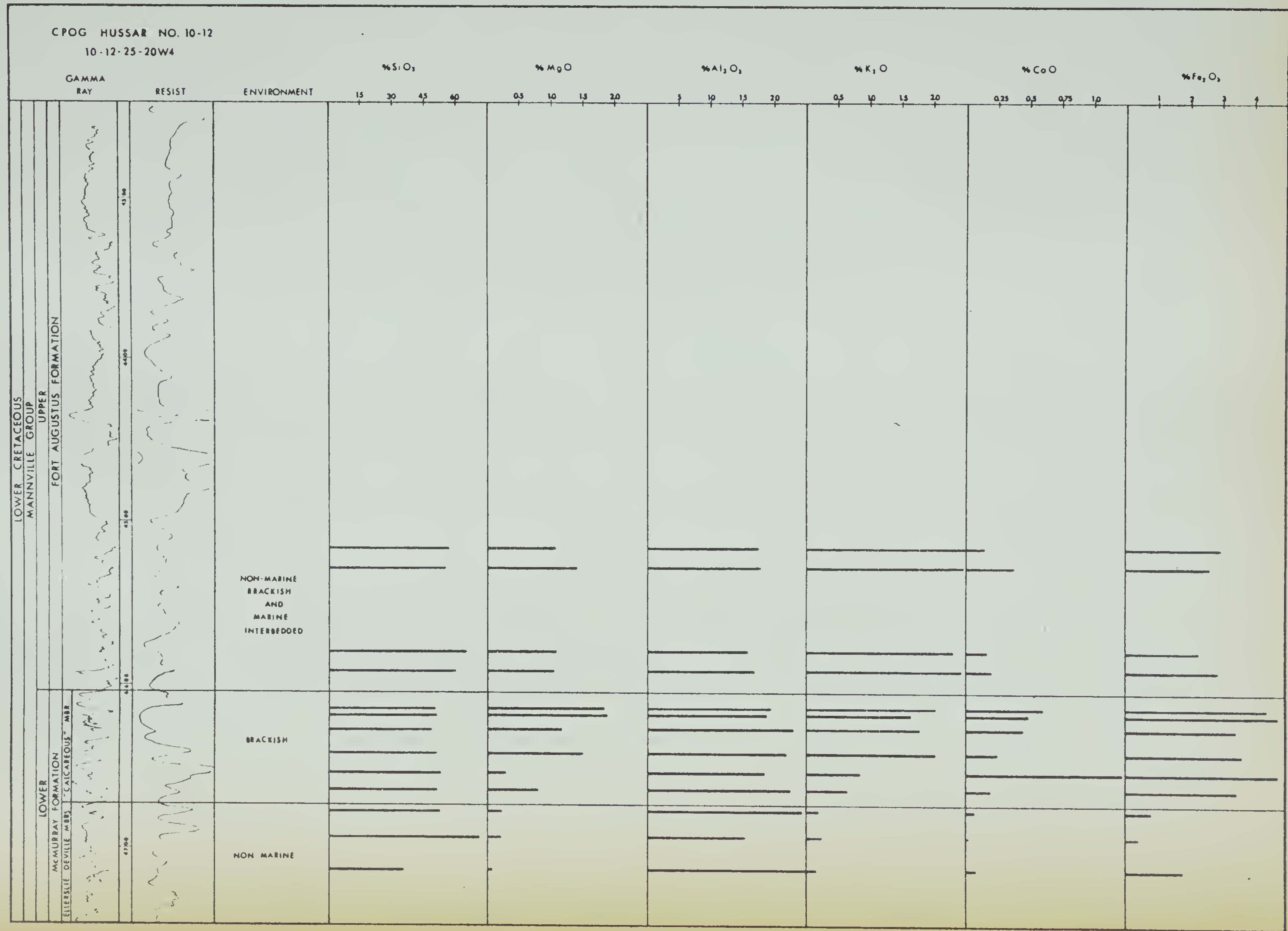
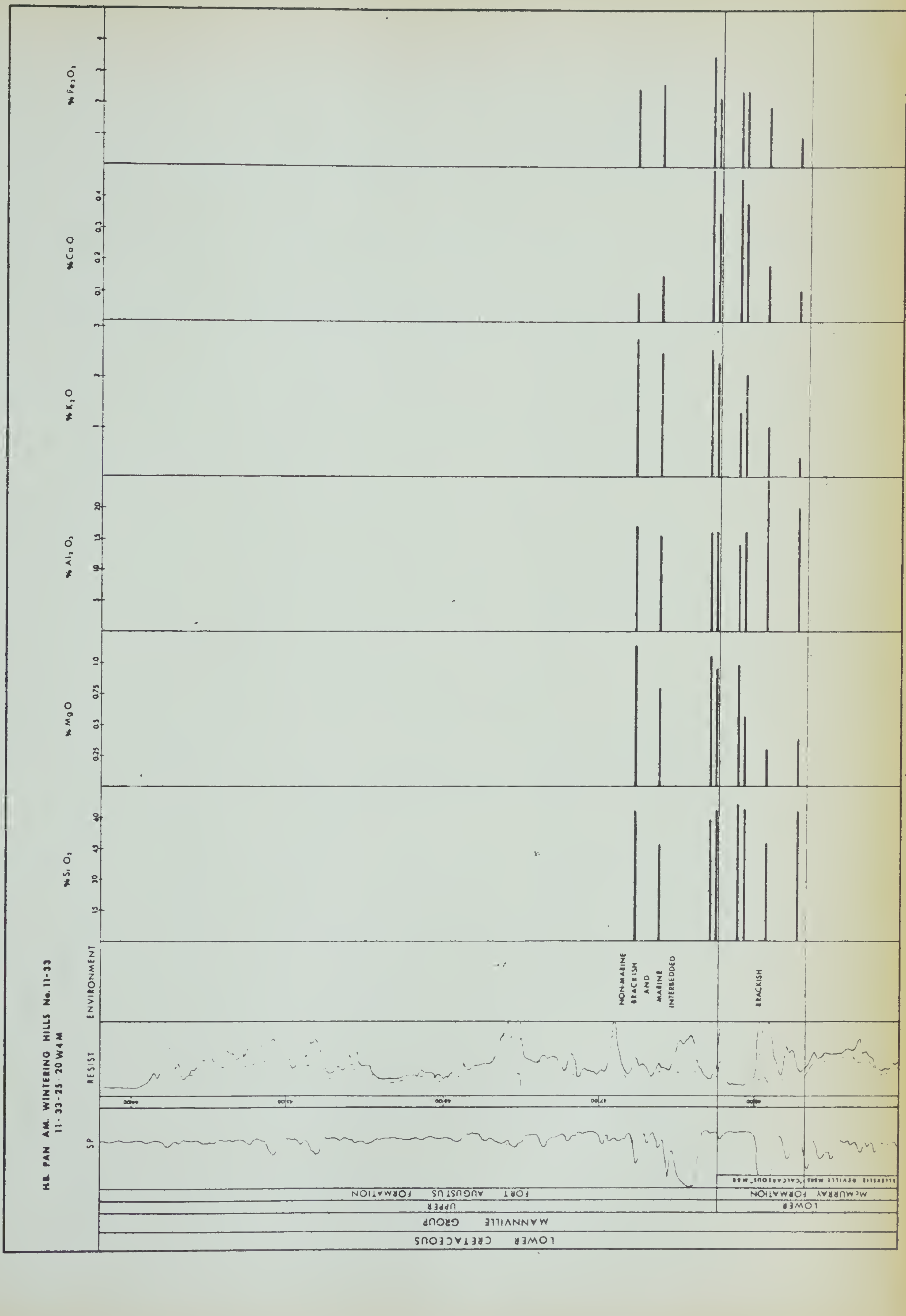

MOBIL CPR PARFLESH No 6 20
6 20 24 21W4M
GAMMA RAY
RESIST
ENVIRONMENT
% Si O2
% Mg O
% Al2 O3
% K2 O
% Ca O
% Fe2 O3
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
FORT AUGUSTUS FORMATION
LOWER
McMURRAY FORMATION
ELLERSLIE DEVILLE MBRS
CALCAREOUS MBR
NON MARINE BRACKISH AND MARINE INTERBEDDED
BRACKISH

FIGURE II-IV



CPOG HUSSAR NO. 10-12
10-12-25-20W4
GAMMA RAY
RESIST
ENVIRONMENT
% SiO_2
% MgO
% Al_2O_3
% K_2O
% CaO
% Fe_2O_3
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
FORT AUGUSTUS FORMATION
LOWER
McMURRAY FORMATION
"CALCAREOUS" MBR
ELLERSLIE DEVILLE MBRS
NON-MARINE BRACKISH AND MARINE INTERBEDDED
BRACKISH
NON MARINE

FIGURE II-V



H.B. PAN AM. WINTERING HILLS No. 11-33
11-33-25-20 W4M
SP
RESIST
ENVIRONMENT
NON-MARINE BRACKISH AND MARINE INTERBEDDED
BRACKISH
% SiO_2
% MgO
% Al_2O_3
% K_2O
% CaO
% Fe_2O_3
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
LOWER
FORT AUGUSTUS FORMATION
McMURRAY FORMATION

FIGURE II-VI

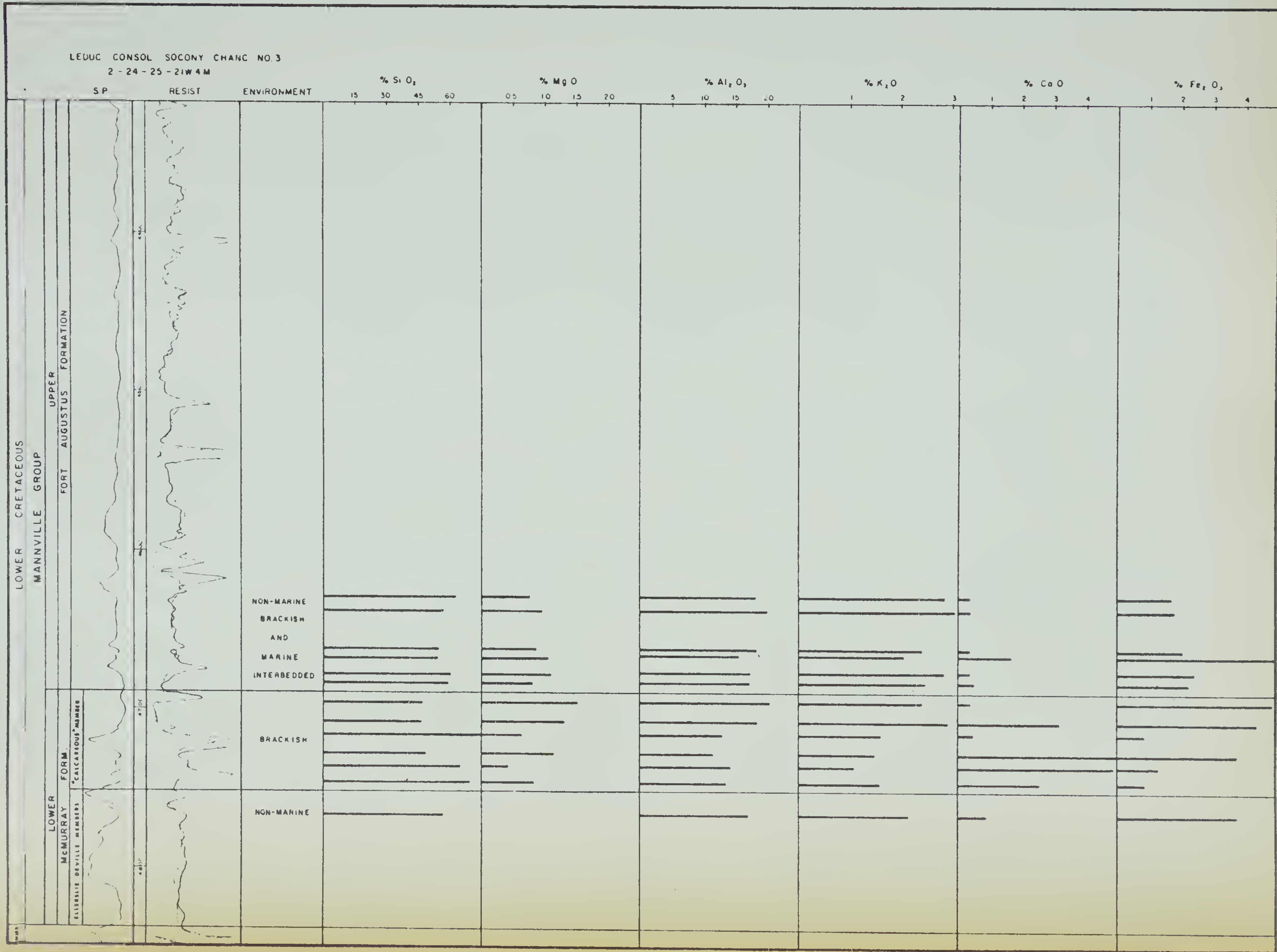


FIGURE II-VII

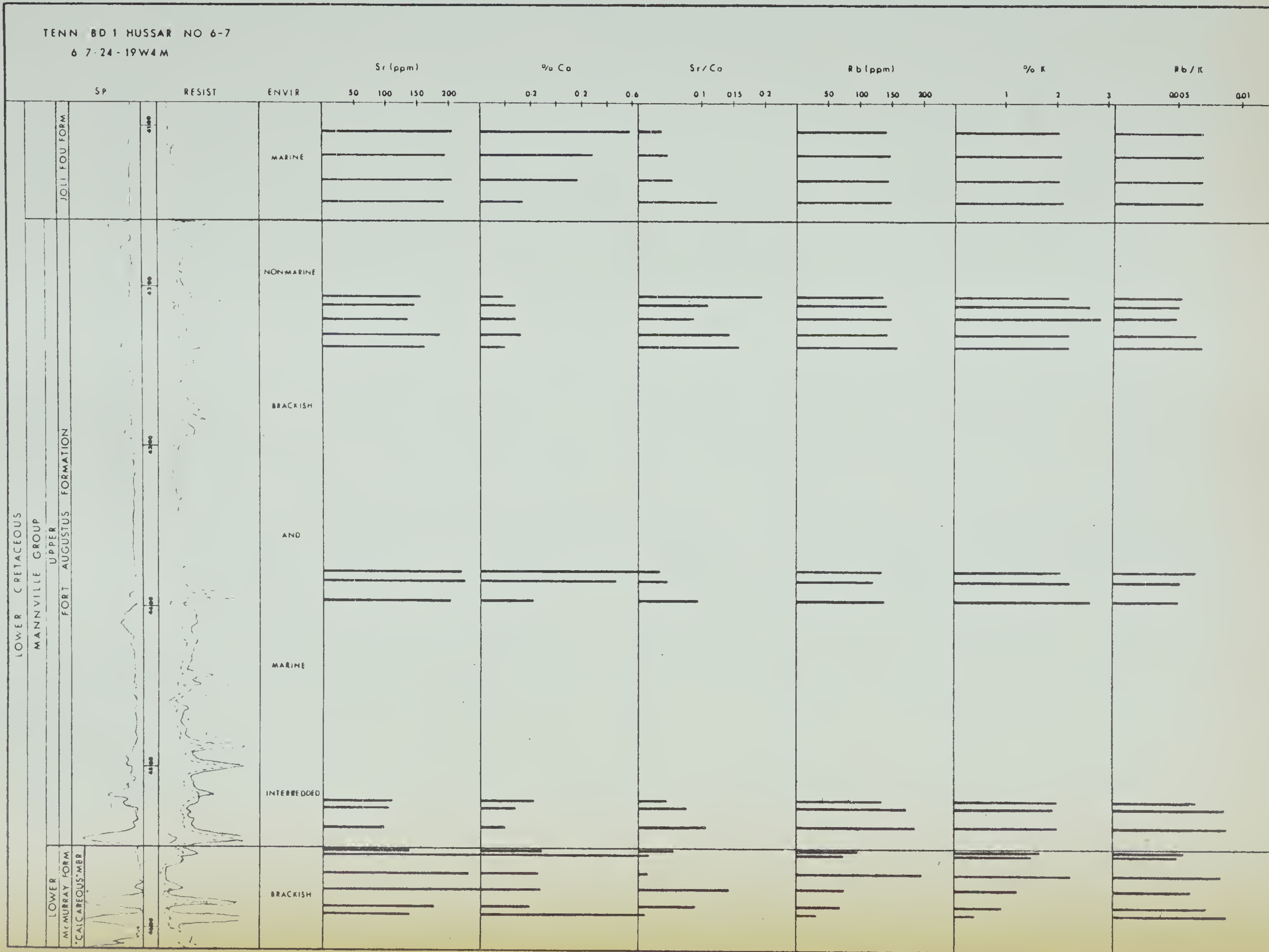

TENN BD 1 HUSSAR NO 6-7
6 7-24-19W4M
SP
RESIST
ENVIR
Sr (ppm)
50 100 150 200
% Ca
0.2 0.2 0.6
Sr/Ca
0.1 0.15 0.2
Rb (ppm)
50 100 150 200
% K
1 2 3
Rb/K
0.005 0.01
MARINE
NON-MARINE
BRACKISH
AND
MARINE
INTERBEDDED
BRACKISH
LOWER CRETACEOUS
MANNVILLE GROUP
JOLI FOU FORM
UPPER
FORT AUGUSTUS FORMATION
LOWER
McMURRAY FORM
"CALCAREOUS" MBR

FIGURE 12-1

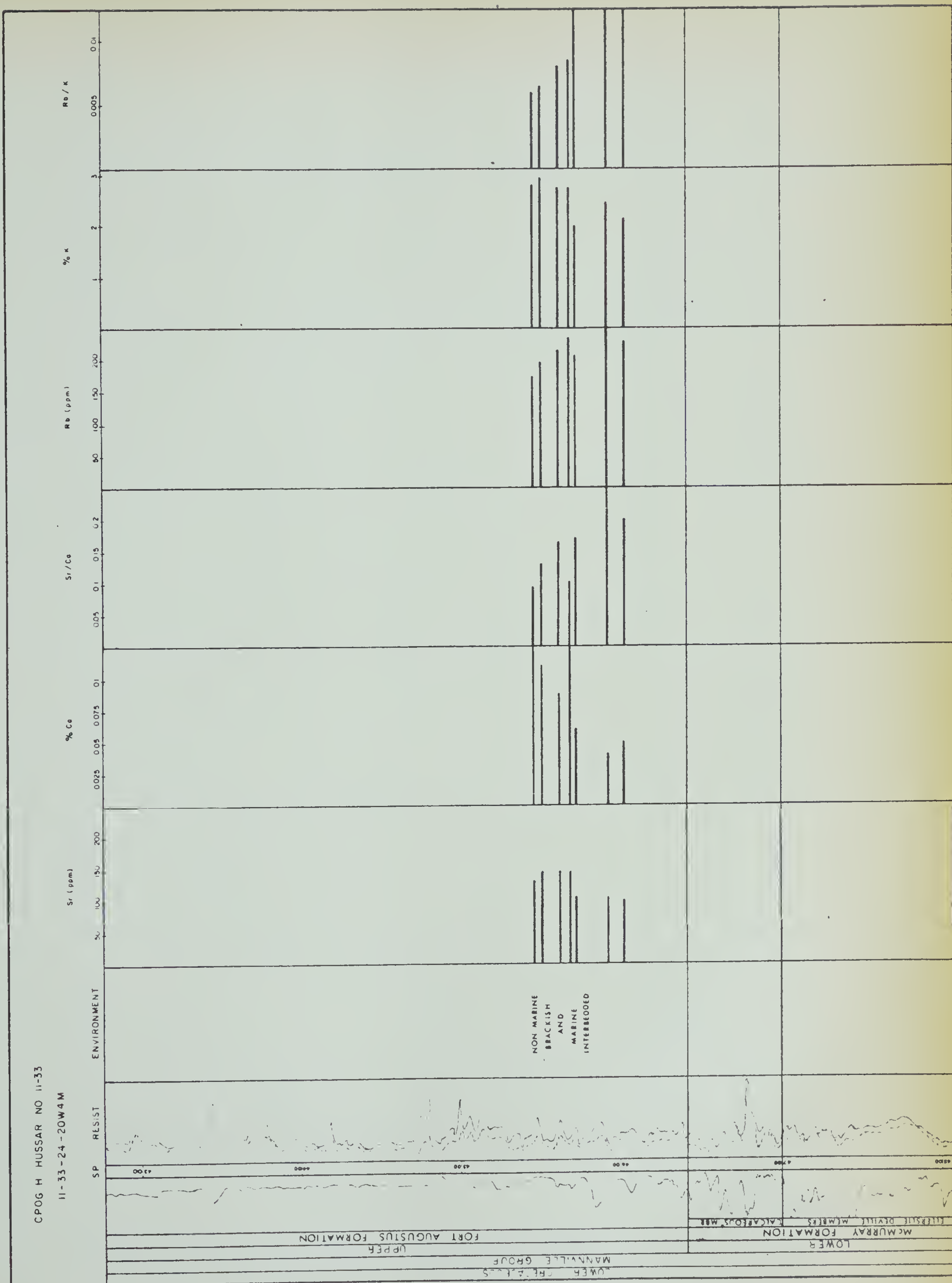

CPOG H HUSSAR NO 11-33
11-33-24-20W4M
SP
RESIST
ENVIRONMENT
Sr (ppm)
% Ca
Sr/Ca
Rb (ppm)
% K
Rb/K
NON MARINE
BRACKISH
AND
MARINE
INTERBEDDED
FORT AUGUSTUS FORMATION
UPPER
McMURRAY FORMATION
LOWER
MANNVILLE GROUP

FIGURE 12-11

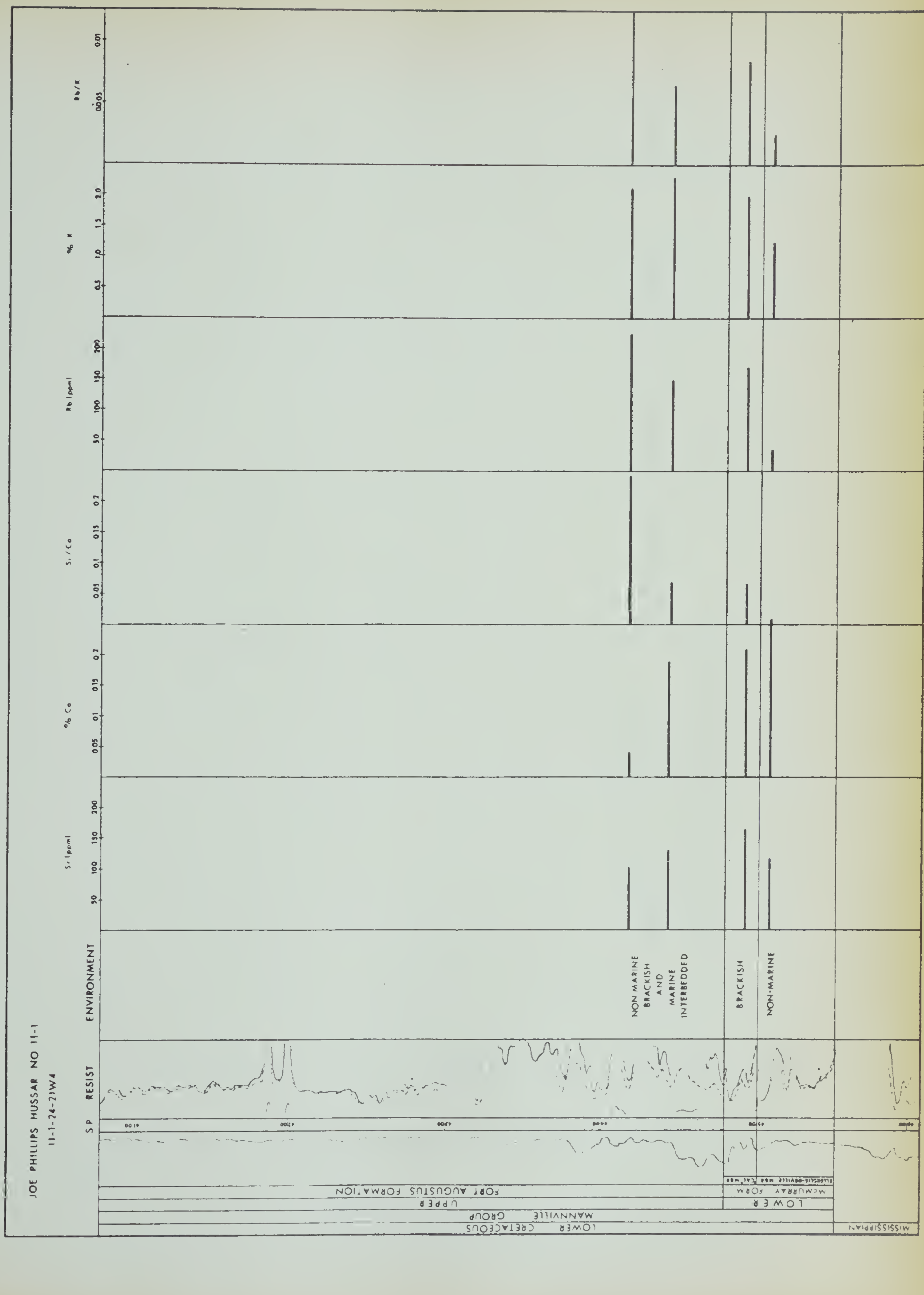


FIGURE 12-III

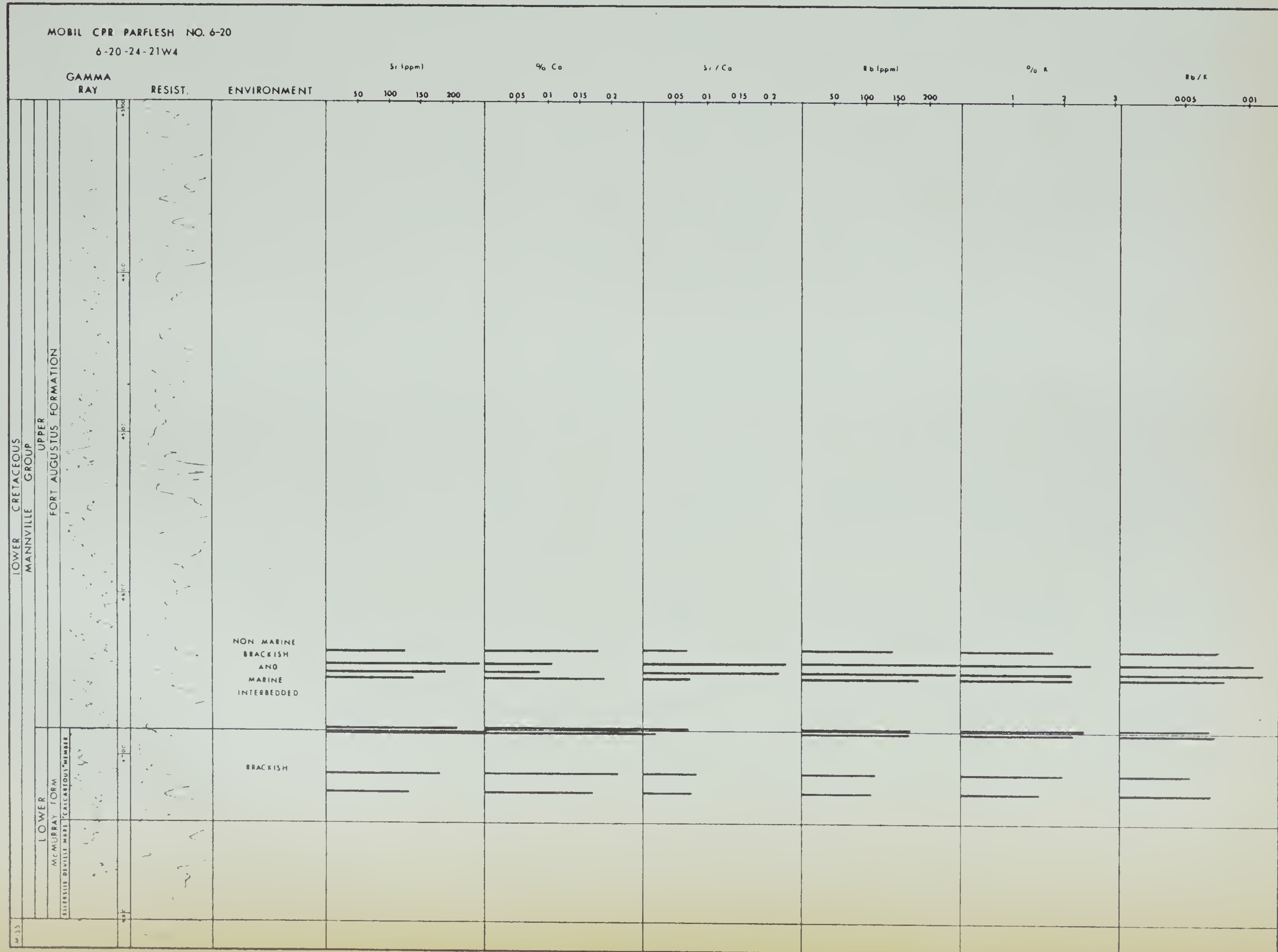
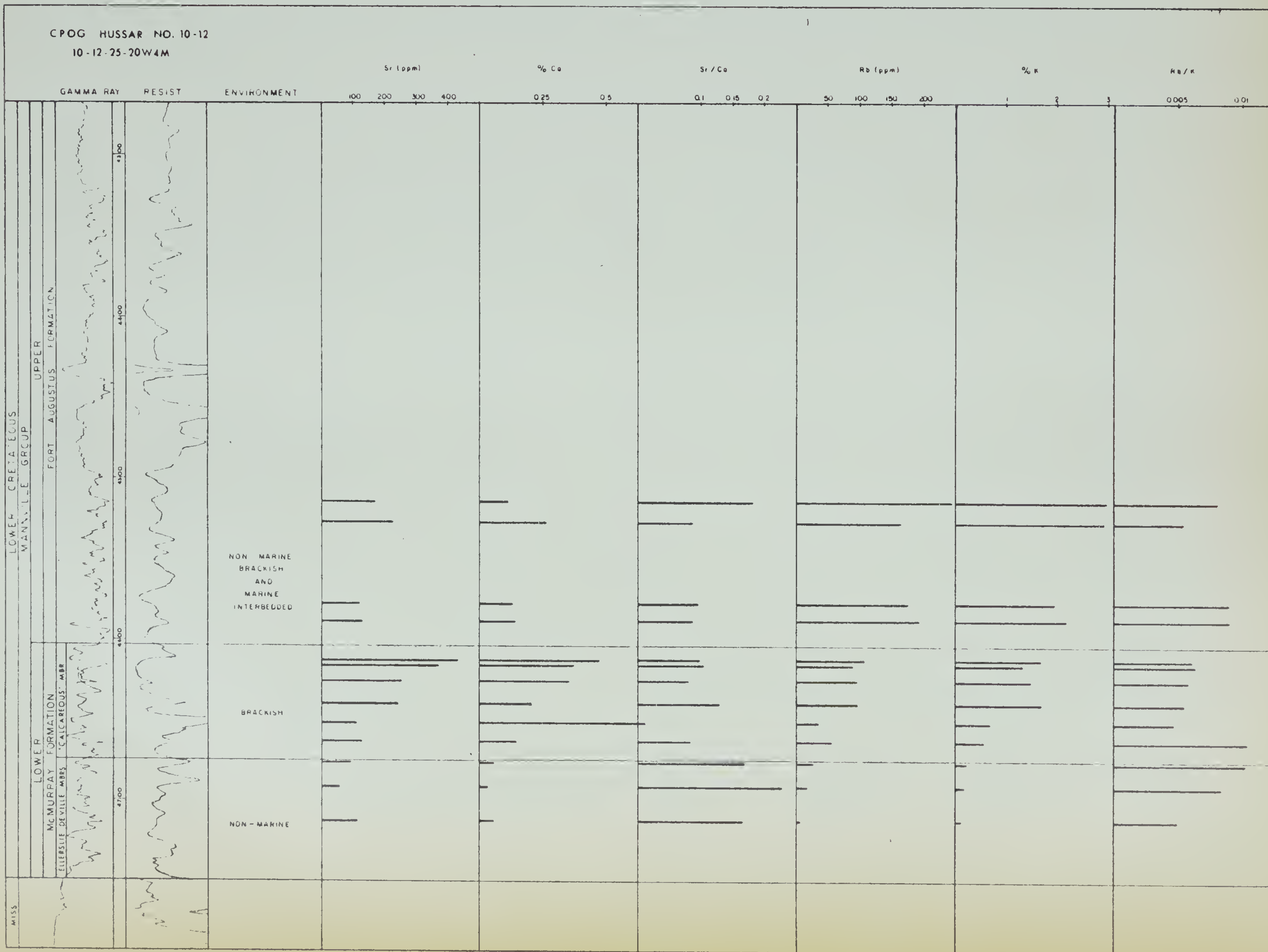

MOBIL CPR PARFLESH NO. 6-20
6-20-24-21W4
GAMMA RAY
RESIST.
ENVIRONMENT
Sr (ppm)
50 100 150 200
% Ca
0.05 0.1 0.15 0.2
Sr / Ca
0.05 0.1 0.15 0.2
Rb (ppm)
50 100 150 200
% K
1 2 3
Rb / K
0.005 0.01
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
FORT AUGUSTUS FORMATION
LOWER
McMURRAY FORM
NON MARINE BRACKISH AND MARINE INTERBEDDED
BRACKISH

FIGURE 12-IV



CPOG HUSSAR NO. 10-12
10-12-25-20W4M
GAMMA RAY
RESIST
ENVIRONMENT
Sr (ppm)
100 200 300 400
% Ca
0.25 0.5
Sr / Ca
0.1 0.15 0.2
Rb (ppm)
50 100 150 200
% K
1 2 3
Rb / K
0.005 0.01
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
FORT AUGUSTUS FORMATION
LOWER
McMURRAY FORMATION
'CALCAREOUS' MBR
ELLERSLIE DEVILLE MBRS
MISS
4400
4500
4600
4700
NON MARINE
BRACKISH
AND
MARINE
INTERBEDDED
BRACKISH
NON-MARINE

FIGURE 12-V

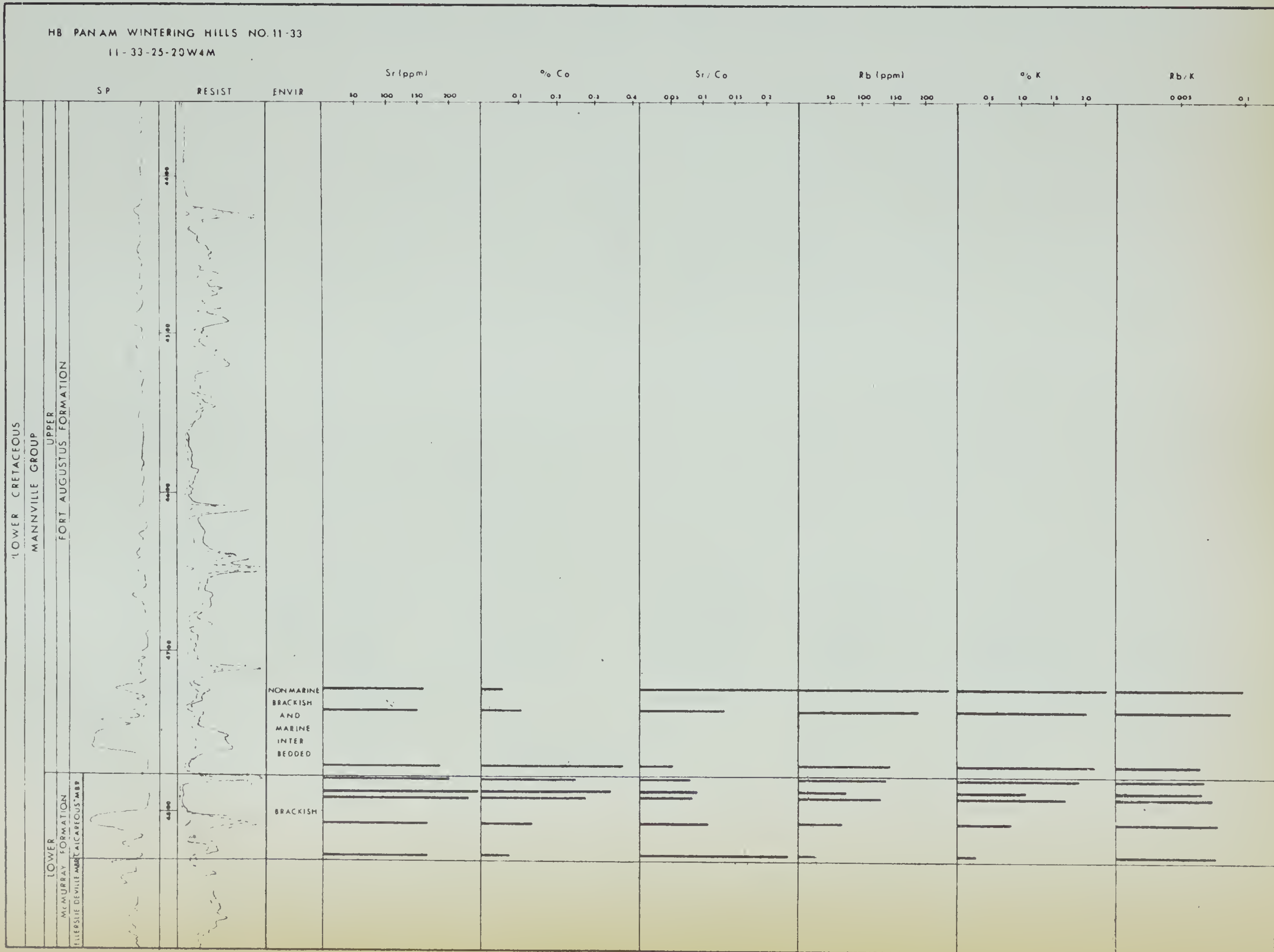

HB PAN AM WINTERING HILLS NO. 11-33
11-33-25-20W4M
SP
RESIST
ENVIR
Sr (ppm)
50 100 150 200
% Ca
0.1 0.2 0.3 0.4
Sr / Ca
0.05 0.1 0.15 0.2
Rb (ppm)
50 100 150 200
% K
0.5 1.0 1.5 2.0
Rb / K
0.005 0.1
NON MARINE
BRACKISH
AND
MARINE
INTER
BEDDED
BRACKISH
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
FORT AUGUSTUS FORMATION
LOWER
McMURRAY FORMATION
ELLERSLIE DEVILLE MBR
CALCAREOUS MBR

FIGURE 12-VI

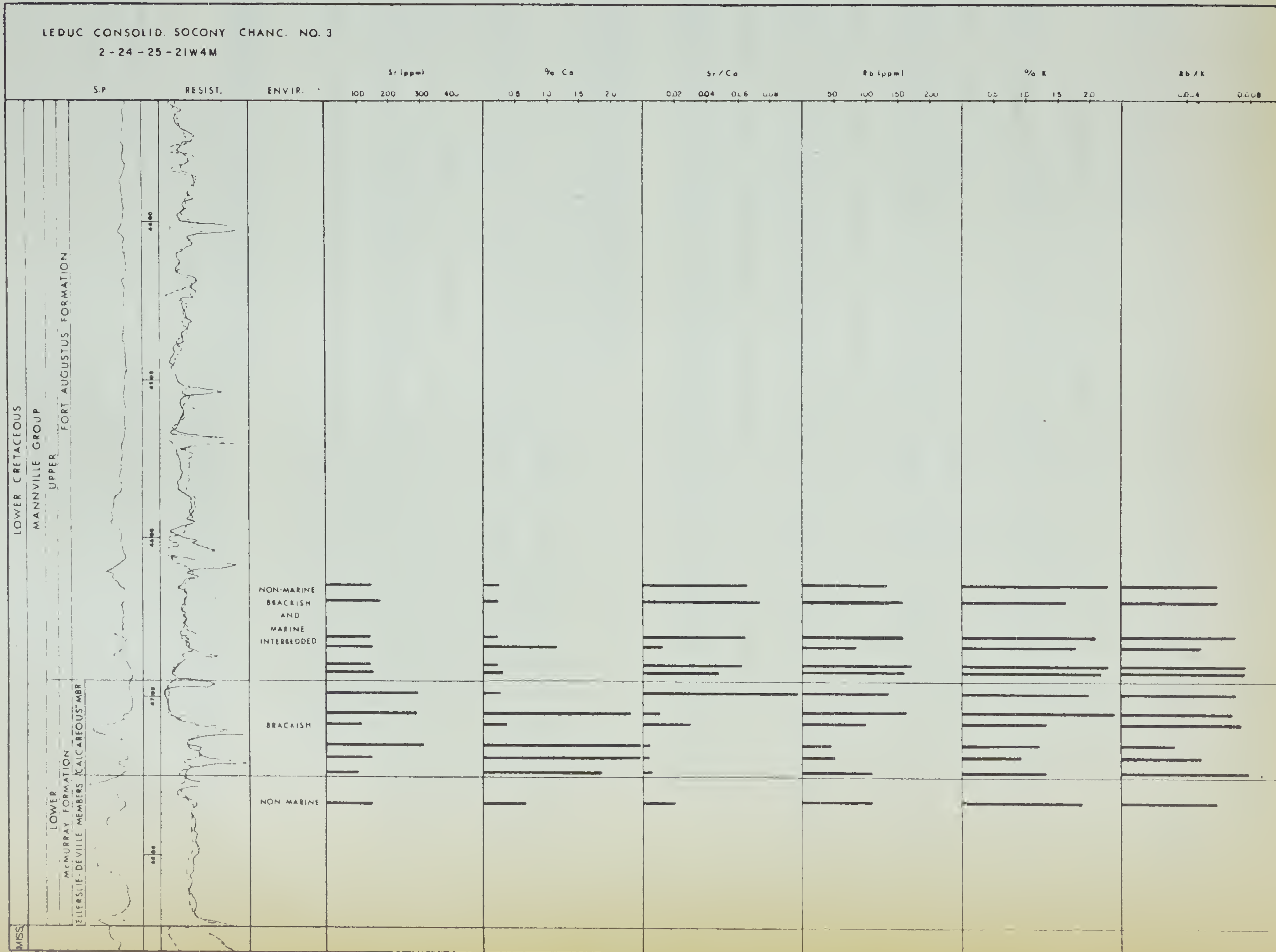


FIGURE 12-VII

Williams, 1965) is included for the purpose of comparison. The totals fall somewhat below 100 percent because the water and Na_2O content for the samples were not determined.

The shales from the Ellerslie-Deville Members are similar to those of the overlying "Calcareous" member in SiO_2 content. The shales are low in MgO, K_2O, CaO, Fe_2O_3 and are high in Al_2O_3. The samples from the "Calcareous" member are low in SiO_2, MgO, Al_2O_3, K_2O and are high in CaO and Fe_2O_3 when compared with shales from the overlying Fort Augustus Formation. Fort Augustus shales are high in SiO_2, Al_2O_3, K_2O and are low in MgO, CaO and Fe_2O_3 when compared with Joli Fou shales which have on average higher MgO and Fe_2O_3 than shales from the other formations of this study.

Distribution of Minor Constituents

The Sr and Rb content of each sample was determined in order that the proxy relationships with Ca and K respectively could be studied. Again as with the major constituent variations, the results are shown graphically in Figures 12-I through 12-VII and the averages for the various formations or members are given in Table 3-II along with data from Campbell and Williams (1965).

Significance of Geochemical Results

In order to evaluate the broad geochemical implications of the shale analyses, the average chemical composition of the 75 shale samples has been calculated. For the purpose of comparison, the composition of shales from Imperial Sprucefield No. 1 (Campbell and Williams, 1965), the composition

Table 4

Comparison with Composition of an Average Shale and the Continental Crust

	This Study Shale [1]	Campbell and Williams Shale [2]	Clarke Avg. Shale [3]	Clarke and Washington Continent [4]	MacDonald Continent [5]	Goldschmidt Continent [6]	MacDonald Crust [5]
SiO_2	56.00	64.83	58.10	60.18	58.90	59.12	56.43
MgO	1.06	2.66	2.44	3.56	3.48	3.30	4.61
Al_2O_3	18.97	15.72	15.40	15.61	15.34	15.82	15.63
K_2O	2.29	2.50	3.24	3.19	3.13	3.93	2.58
CaO	0.86	2.42	3.11	5.17	5.06	3.07	6.28
Fe_2O_3	2.66	5.08	6.47	7.40	7.19	6.99**	8.71
Rb	137 ppm	97 ppm	194 *	198 ppm *	187 ppm *	235 ppm *	154 ppm *
Sr	188 ppm	210 ppm	679 *	1130 ppm *	1106 ppm *	671 ppm *	1373 ppm *
Rb/Sr	0.73	0.46	0.29 *	0.18 *	0.17 *	0.35 *	0.11 *

* Calculated value (see text)
** This value is $Fe_2O + FeO$
1 This study average of 75
2 Campbell and Williams (1965) p. 86 ,(average of 113)
3 Clarke (1924), p. 34 (average of 78)
4 Clarke and Washington, from Mason (1952), p. 39
5 MacDonald (1959), p. 478
6 Goldschmidt, from Mason (1952), p. 40

of an average shale (Clarke,1924) and the continental crust (Clarke and Washington and Goldschmidt, in Mason, 1952; MacDonald, 1959) are included in Table 4 along with data for the composition of the entire crust (MacDonald, 1959).

The shales from this study show reasonably good agreement in SiO_2 with the other averages. The Al_2O_3 content is somewhat higher than the other averages; the averages from this study appear low in MgO, K_2O and appreciably lower in CaO and Fe_2O_3 when compared with the results of Campbell and Williams (1965). No explanation for these variations is obvious.

The Rb and Sr averages for this study are from actual determinations, whereas most of the others are calculated. The calculations were made on the basis of a direct proxy relationship of Rb for K and Sr for Ca. On this basis the measured values for Rb (137 ppm) and for Sr (188 ppm) were multiplied by factors depending on the ratio of K_2O (in the case of Rb) and CaO (in the case of Sr) of the other analyses to K_2O and CaO in the present study to get Rb and Sr values in columns 3 to 7. The Rb/Sr ratio of 0.73 determined for the shales of this study is somewhat higher than the 0.46 value obtained by Campbell and Williams (1965) and also higher than the 0.50 value given by Faure and Hurley (1963) for an average of 29 Rb and 69 Sr determinations on shales. The calculated continental Rb/Sr values of 0.18 and 0.17 in columns 4 and 5 are somewhat lower than the 0.25 value accepted by Faure and Hurley. By assuming a simple proxy relationship, the crustal ratio of 0.11 can be calculated from the analyses, a value which is somewhat lower than many recent measurements

(Faure and Hurley, 1963).

The variation in the chemical composition of the shales follows a pattern which suggests an environmental control for these rocks. The composition of the shales of the Ellerslie-Deville Members reflects the maturity of the detritus to be expected in a continental environment of low relief in that the cations have been extensively leached producing kaolinite as the main clay mineral.

In general, the "Calcareous" member shows a decrease in SiO_2 from bottom to top and an increase in MgO, K_2O, CaO and Fe_2O_3 (Figures 11-I throught 11-VII). The shales of this unit were formed in environments that were consecutively continental, brackish and marine.

The shales of the Fort Augustus Formation show a composition which on average suggests a marine environment as indicated by high Rb/K ratios (Campbell and Lerbekmo, 1963). In detail, however, there appear to be oscillatory trends which suggest a changing environment or possibly a change in source material. On the basis of K-Ar dates of 120 - 220 m.y. from feldspars taken from the Grand Rapids Formation of central Alberta, Williams, Campbell and Steen (1962) concluded that these feldspars came from a Mesozoic source in the Cordillera. The increase in K_2O content in Fort Augustus shales supports this concept.

The portion of the Joli Fou Formation studied contains shales of uniform composition suggesting a constant marine environment. The K_2O content of these shales agrees closely with those values obtained by Campbell and Williams (1965) and by Cameron (1966).

Chapter 6

TECTONIC FRAMEWORK AND ENVIRONMENT OF DEPOSITION

Introduction

Many variable regional and local factors have complexly related and overlapping effects on the sediment deposited in a particular location at a given time. It is usually very difficult to observe the final product, eliminate the effects of diagenesis, movement and metamorphism, and interpret the role of the various factors. This task is rendered somewhat easier in the case of the Lower Cretaceous Series in the Alberta plains because of the relatively slight effect of diagenesis and movement and the absence of metamorphism.

In this study the regional data regarding the tectonic and sedimentologic factors affecting the sediments of the Mannville Group are based mainly on the work of Rudkin (1964), Glaister (1959) and Williams (1960, 1963). The new data contained herein are concerned mainly with a better definition of the paleotopography, paleogeology and tectonics in a small part of the depositional area.

Tectonic Framework

The tectonic pattern that existed in Western Canada during Early Cretaceous time represented a major change from previous patterns. The

Nevadan or Coast Range orogeny had commenced toward the end of Late Jurassic time expelling the Jurassic sea and raising and intruding the Coast Range uplift along the Pacific coast and the Cassiar-Omineca and Nelson uplifts just west of the present day Rocky Mountain Trench (Rudkin, 1964).

The uplifts supplied vast quantities of clastic sediment to the enclosed intermontane basins and the large western interior basin to the east. The sandstone/shale ratio trends on the lithofacies maps of Glaister (1959) and Rudkin (1964) demonstrate the effect, not only of a western source in the western interior, but also of an eastern source which was probably not far beyond the present zero erosional edge of the Lower Cretaceous in northern Saskatchewan and Manitoba. Heavy mineral studies by Mellon and Wall (1956) and Williams (1960, 1963) as well as radiometric dating by Williams, Baadsgaard, and Steen (1962), also give evidence, especially in the Lower Mannville Group, of a Precambrian Shield source area.

Environment of Deposition

Figure 6 shows the sub-Cretaceous paleotopography, paleogeology and valley trends. An extended period of intense weathering and erosion, during which time a residual mantle developed on the exhumed Mississippian landscape occurred prior to deposition of the McMurray Formation. The drainage system on this sub-Cretaceous surface was responsible for re-distribution and re-working of part of this mantle.

The sub-Cretaceous surface appears to have sloped to the north and in Early Cretaceous time, marine sedimentation commenced to the north of the

studied area. In the Hussar area, valleys occupied by westerly flowing streams probably joined a major valley system which flowed northerly toward the sea. Contemporaneous with the non-marine deposition of Lower Mannville sediments over most of Alberta, part of the marine Garbutt Formation was being deposited north of approximately 59° north latitude (Rudkin, 1964). Depending on the sediment supply, prevailing currents and the irregular topography on the sub-Cretaceous surface, shoreline sands and associated lagoonal deposits accumulated along the margins of this sea. Channel and associated flood plain deposits of the Ellerslie Member completed the filling of the major irregularities in the sub-Cretaceous landscape shoreward of the coastline.

Following early Lower Mannville deposition, the northern sea transgressed southward, initially forming estuaries in the drowned valleys. The "Calcareous" member was deposited in this and adjacent environments. Continued transgression led to the deposition of the Fort Augustus Formation and complete burial of the ridges. Details of subsequent drainage systems and topography, as the prograding mass of Fort Augustus sediments advanced from the western mountains are difficult to ascertain. Relative rises in sea level or decreases in sediment supply led to occasional transgression and re-working to produce the clean sandstones which occur within the Fort Augustus Formation. These sands represent possibly the interfingering of the western derived sediments with more mature sediments from the Shield.

Mannville sedimentation was brought to a close in late Albian time with the advance of the boreal sea to join with a sea from the Gulf of Mexico forming the extensive Colorado sea of the interior.

SUMMARY AND CONCLUSIONS

The Mannville Group of the Hussar area is divided into a lower McMurray Formation and an upper Fort Augustus Formation. The McMurray Formation is further subdivided into Deville-Ellerslie and "Calcareous" Members in ascending order.

The Mannville Group was deposited on an erosional surface of relatively low relief, the topographic features of which were controlled by the nature of the subcropping Paleozoic (Mississippian) Formations. Subsequent valleys on the Paleozoic surface in the Hussar area were occupied by westerly-flowing streams which probably joined a major valley system which flowed northerly over wide flood plains toward the sea during early Lower Mannville (McMurray) time. As the area slowly subsided, the northern sea transgressed southward initially forming estuaries in the drowned valleys. Continued transgression led to the deposition of Upper Mannville (Fort Augustus) sediments and complete burial of topographic features.

Sandstones of the McMurray Formation are notably low in feldspar and show wide variations in rock fragment content indicating reworking of detritus and local secondary sources, particularly in the lower beds. Sandstones of the Fort Augustus Formation are noticeably richer in rock fragments and feldspar and their composition is more variable. Feldspars from acid volcanoes and possibly from erosion of plutonic masses formed an increasing proportion of coarse detritus supplied to the interior sea in late Mannville time.

Variations in the chemical composition of the shales follow a pattern which suggests environmental control. Shales of the McMurray Formation exhibit the compositions one would expect of a well worked continental sequence. The "Calcareous" member is transitional and the shales assume a marine aspect toward the top. The Fort Augustus Formation contains shales that suggest both marine and continental or brackish affinities. The Joli Fou shales are distinctly marine on the basis of chemical criteria.

The Rb/Sr ratio for all the shales analysed is 0.73 which is somewhat higher than has been previously reported. By assuming a simple proxy relationship, a crustal Rb/Sr ratio of 0.11 can be calculated, a value which is slightly lower than many recent measurements.

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APPENDIX A

LOCATIONS OF SAMPLES

LOCATIONS OF SAMPLES

Samples for Thin Section Study

The first number is the Department of Geology, University of Alberta, catalogue number for the prepared thin section. This is followed by the thesis suite collection number in brackets. The sample depths have been taken from electric logs.

Tenn BD 1 Hussar No. 6-7

Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M

Elevation 3030 feet (K.B.)

No.		Depth below K.B. (Feet)
5692	(HPH-1)	4237
5693	(HPH-2)	4507
5694	(HPH-3)	4514
5695	(HPH-4)	4540
5696	(HPH-5)	4585
5697	(HPH-6)	4595
5698	(HPH-7)	4609
5699	(HPH-8)	4618
5700	(HPH-9)	4626
5701	(HPH-10)	4645
5702	(HPH-11)	4686

CPOG H Hussar No. 11-33

Lsd. 11, Sec. 33, Twp. 24, Rge. 20, W4M

Elevation 2994 feet (K.B.)

No.		Depth below K.B. (Feet)
5703	(CHH-1)	4557
5704	(CHH-2)	4561
5705	(CHH-3)	4579 - 80
5706	(CHH-4)	4581
5707	(CHH-5)	4603

Joe Phillips Hussar No. 11-1

Lsd. 11, Sec. 1, Twp. 24, Rge. 21, W4M

Elevation 2834.5 feet (K.B.)

No.		Depth below K.B. (Feet)
5708	(JPH-1)	4422
5709	(JPH-2)	4467 - 68
5710	(JPH-3)	4492-93

Mobil CPR Parflesh No. 6-20

Lsd. 6, Sec. 20, Twp. 24, Rge. 21, W4M

Elevation 2922 feet (K.B.)

No.		Depth below K.B. (Feet)
5711	(MCP-1)	4636
5712	(MCP-2)	4651
5713	(MCP-3)	4669
5714	(MCP-4)	4712 - 13
5715	(MCP-5)	4729

CPOG Hussar No. 10-12

Lsd. 10, Sec. 12, Twp. 25, Rge. 20, W4M

Elevation 3024 feet (K.B.)

No.		Depth below K.B. (Feet)
5716	(CH-1)	4505
5717	(CH-2)	4560
5718	(CH-3)	4670
5719	(CH-4)	4680
5720	(CH-5)	4716

HB Pan Am Wintering Hills No. 11-33

Lsd. 11, Sec. 33, Twp. 25, Rge. 20, W4M

Elevation 3132.1 feet (K.B.)

No.		Depth below K.B. (Feet)
5721	(HPW-1)	4726
5722	(HPW-2)	4756
5723	(HPW-3)	4822
5724	(HPW-4)	4831

Leduc Consolidated Socony Chancellor No. 3

Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M

Elevation 2996 feet (K.B.)

No.		Depth below K.B. (Feet)
5725	(CSC-1)	4621
5726	(CSC-2)	4650
5727	(CSC-3)	4654
5728	(CSC-4)	4671
5729	(CSC-5)	4710
5730	(CSC-6)	4719
5731	(CSC-7)	4738 - 39
5732	(CSC-8)	4749
5733	(CSC-9)	4756 - 57
5734	(CSC-10)	4762
5735	(CSC-11)	4772
5736	(CSC-12)	4779
5737	(CSC-13)	4793
5738	(CSC-14)	4801
5739	(CSC-15)	4810
5740	(CSC-16)	4832

CPOG SW Hussar No. 11-19

Lsd. 11, Sec. 19, Twp. 26, Rge. 20, W4M

Elevation 3047 feet (K.B.)

No.		Depth below K.B. (Feet)
5741	(SWH-1)	4675
5742	(SWH-2)	4702
5743	(SWH-3)	4726

Tenn Ar 1 Hussar No. 14-7

Lsd. 14, Sec. 7, Twp. 26, Rge. 21, W4M

Elevation 2838.9 feet (K.B.)

No.		Depth below K.B. (Feet)
5744	(TAH-1)	4740
5745	(TAH-2)	4753
5746	(TAH-3)	4770
5747	(TAH-4)	4785

Samples for X-Ray Fluorescence Analysis

Tenn BD 1 Hussar No. 6-7

Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M

Elevation 3030 feet (K.B.)

No.	Depth below K.B. (Feet)
HPH X-1	4103 - 04
HPH X-2	4118
HPH X-3	4133
HPH X-4	4147
HPH X-5	4206 - 07
HPH X-6	4212
HPH X-7	4221 - 22
HPH X-8	4230
HPH X-9	4234
HPH X-10	4377 - 78
HPH X-11	4384
HPH X-12	4396 - 97
HPH X-13	4520
HPH X-14	4525
HPH X-15	4536
HPH X-16	4550
HPH X-17	4554
HPH X-18	4566 - 67
HPH X-19	4578
HPH X-20	4587
HPH X-21	4591 - 92

CPOG H Hussar No. 11-33

Lsd. 11, Sec. 33, Twp. 24, Rge. 20, W4M

Elevation 2994 feet (K.B.)

No.	Depth below K.B. (Feet)
CHH X-1	4548
CHH X-2	4552
CHH X-3	4563
CHH X-4	4569
CHH X-5	4574
CHH X-6	4593
CHH X-7	4604

Joe Phillips Hussar No. 11-1

Lsd. 11, Sec. 1, Twp. 24, Rge. 21, W4M

Elevation 2834 feet (K.B.)

No.	Depth below K.B. (Feet)
JPH X-1	4419
JPH X-2	4445
JPH X-3	4495
JPH X-4	4511 - 12

Mobil CPR Parflesh No. 6-20

Lsd. 6, Sec. 20, Twp. 24, Rge. 21, W4M

Elevation 2922 feet (K.B.)

No.	Depth below K.B. (Feet)
MCP X-1	4633
MCP X-2	4642
MCP X-3	4646
MCP X-4	4650
MCP X-5	4682
MCP X-6	4684
MCP X-7	4710
MCP X-8	4722

CPOG Hussar No. 10-12

Lsd. 10, Sec. 12, Twp. 25, Rge. 20, W4M

Elevation 3024 feet (K.B.)

No.	Depth below K.B. (Feet)
CH X-1	4515
CH X-2	4527
CH X-3	4578
CH X-4	4589
CH X-5	4613
CH X-6	4616 - 17
CH X-7	4626
CH X-8	4640
CH X-9	4651
CH X-10	4663
CH X-11	4676
CH X-12	4691
CH X-13	4712

HB Pan Am Wintering Hills No. 11-33

Lsd. 11, Sec. 33, Twp. 25, Rge. 20, W4M

Elevation 3132.1 feet (K.B.)

No.	Depth below K.B. (Feet)
HPW X-1	4722
HPW X-2	4736
HPW X-3	4770
HPW X-4	4774
HPW X-5	4787
HPW X-6	4790
HPW X-7	4806
HPW X-8	4826

Leduc Consolidated Socony Chancellor No. 3

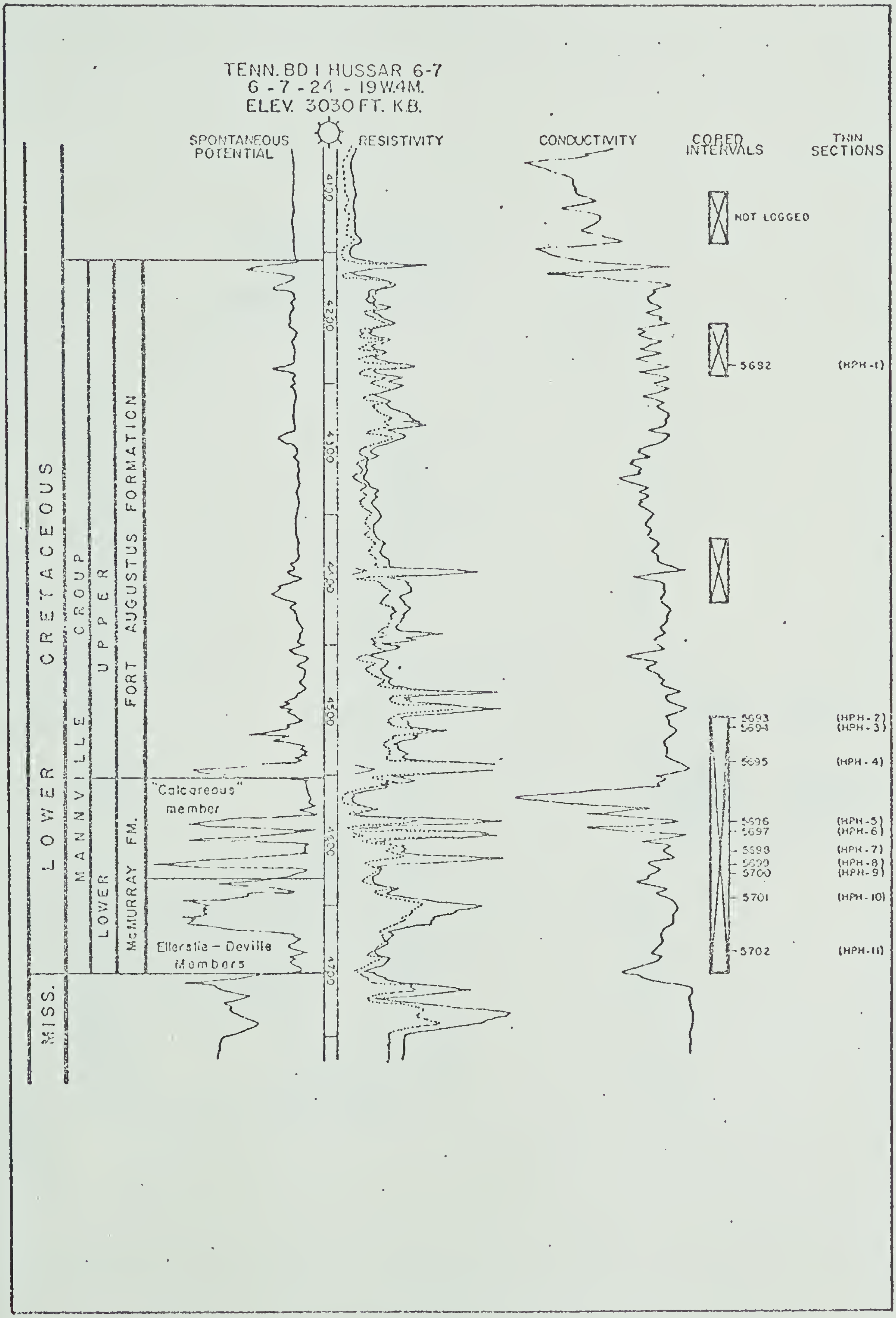
Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M

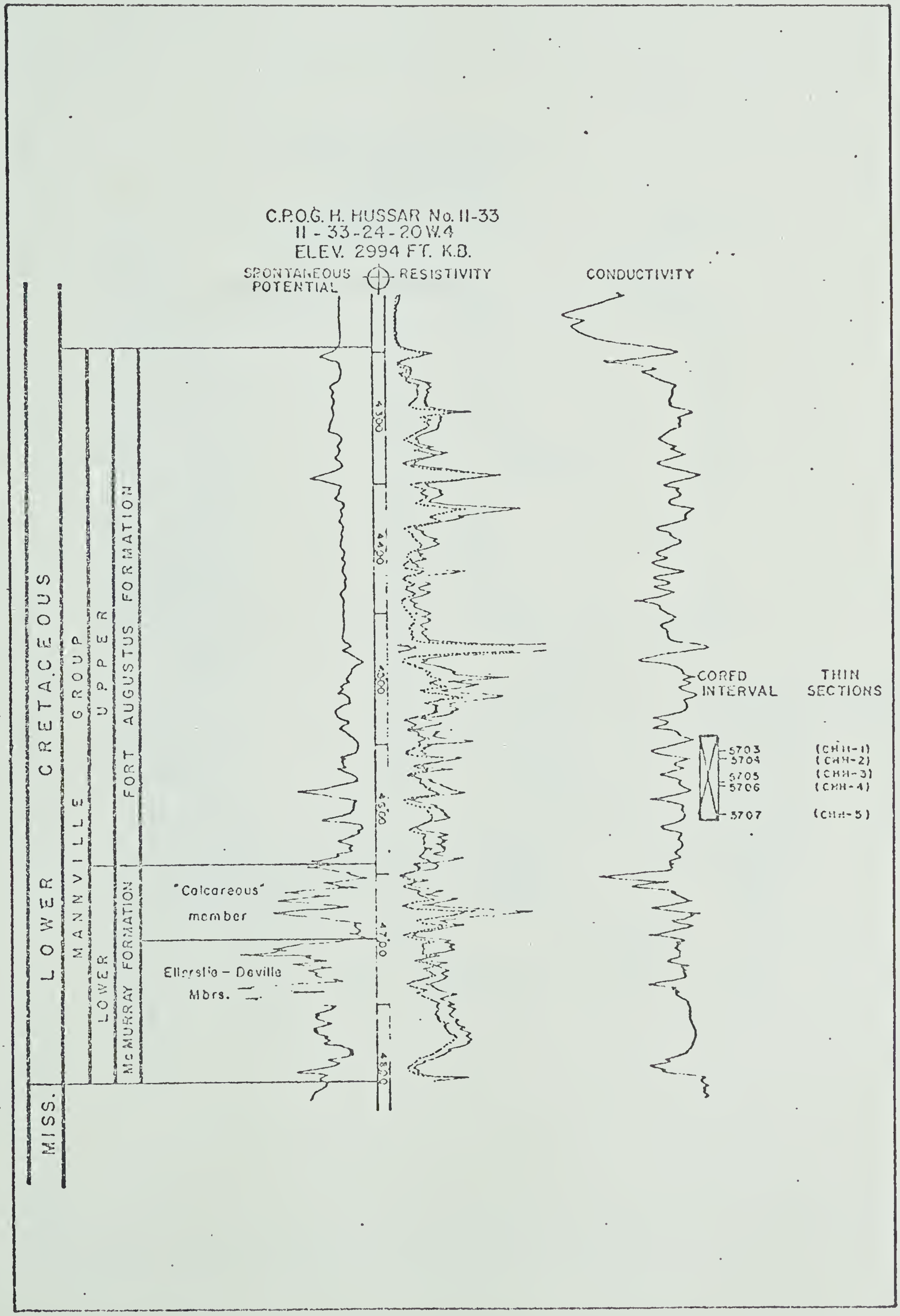
Elevation 2996 feet (K.B.)

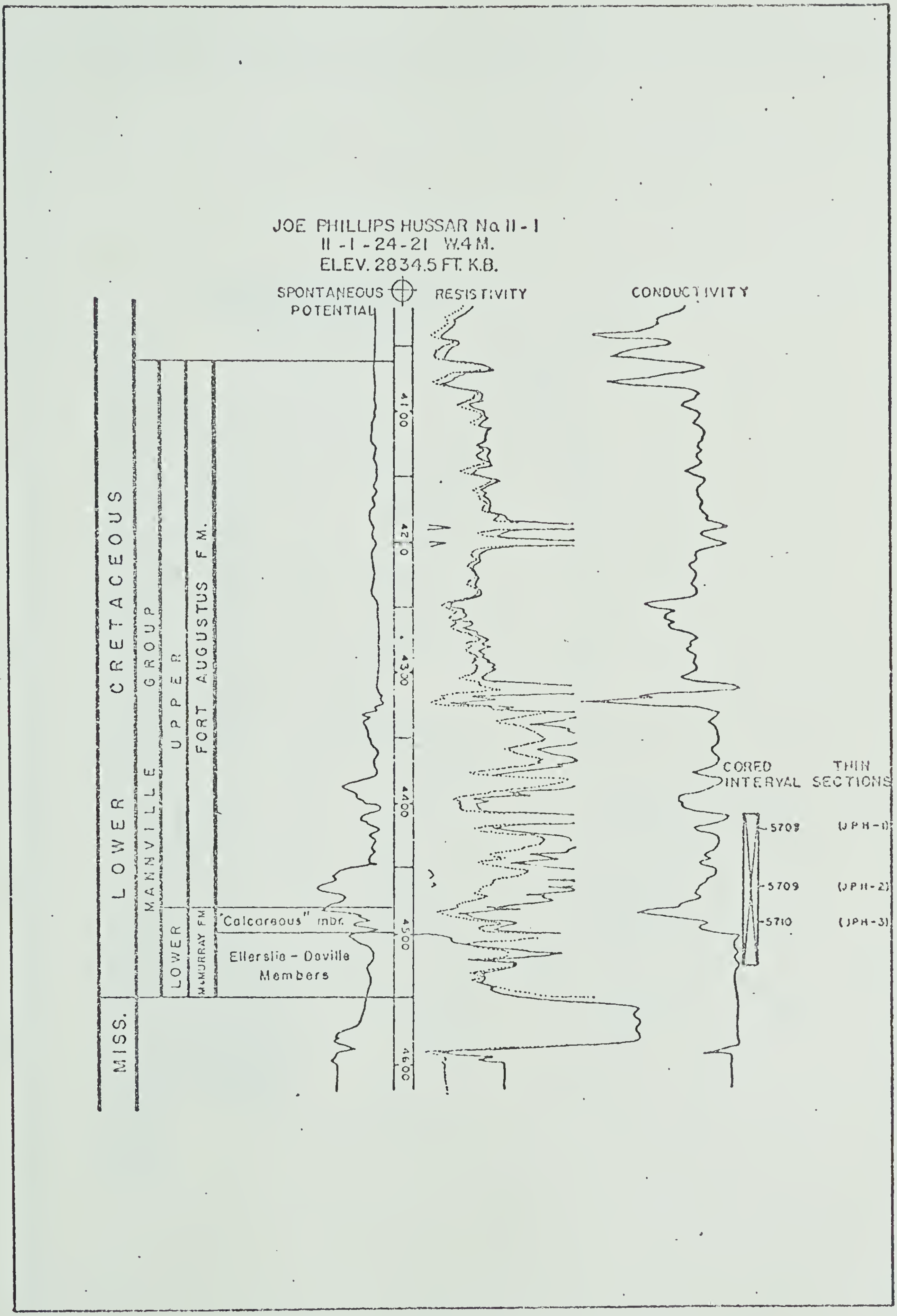
No.	Depth below K.B. (Feet)
CSC X-1	4628
CSC X-2	4638
CSC X-3	4661
CSC X-4	4667 - 68
CSC X-5	4678
CSC X-6	4682
CSC X-7	4688
CSC X-8	4696
CSC X-9	4708
CSC X-10	4715
CSC X-11	4727
CSC X-12	4736 - 37
CSC X-13	4745
CSC X-14	4765

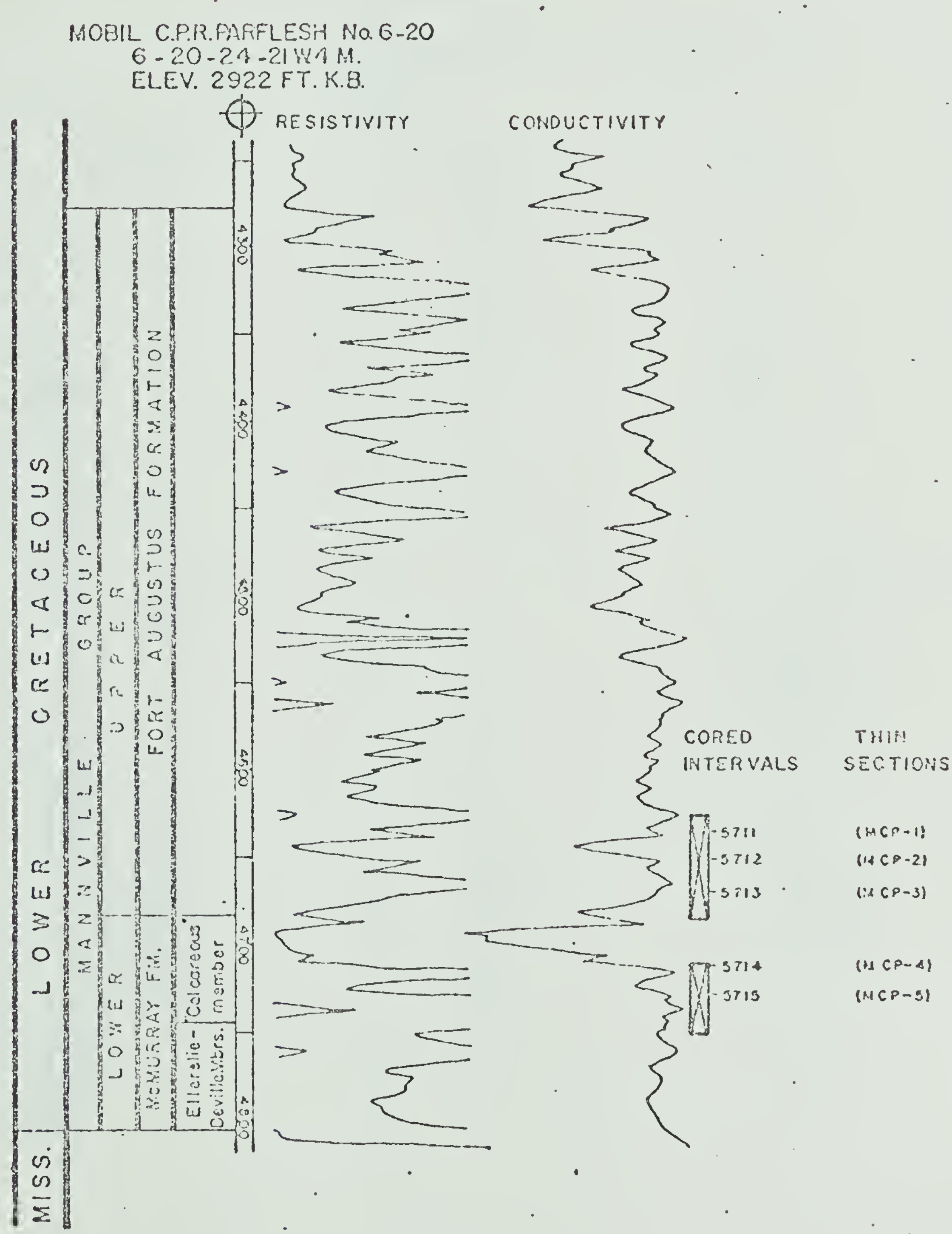
APPENDIX B

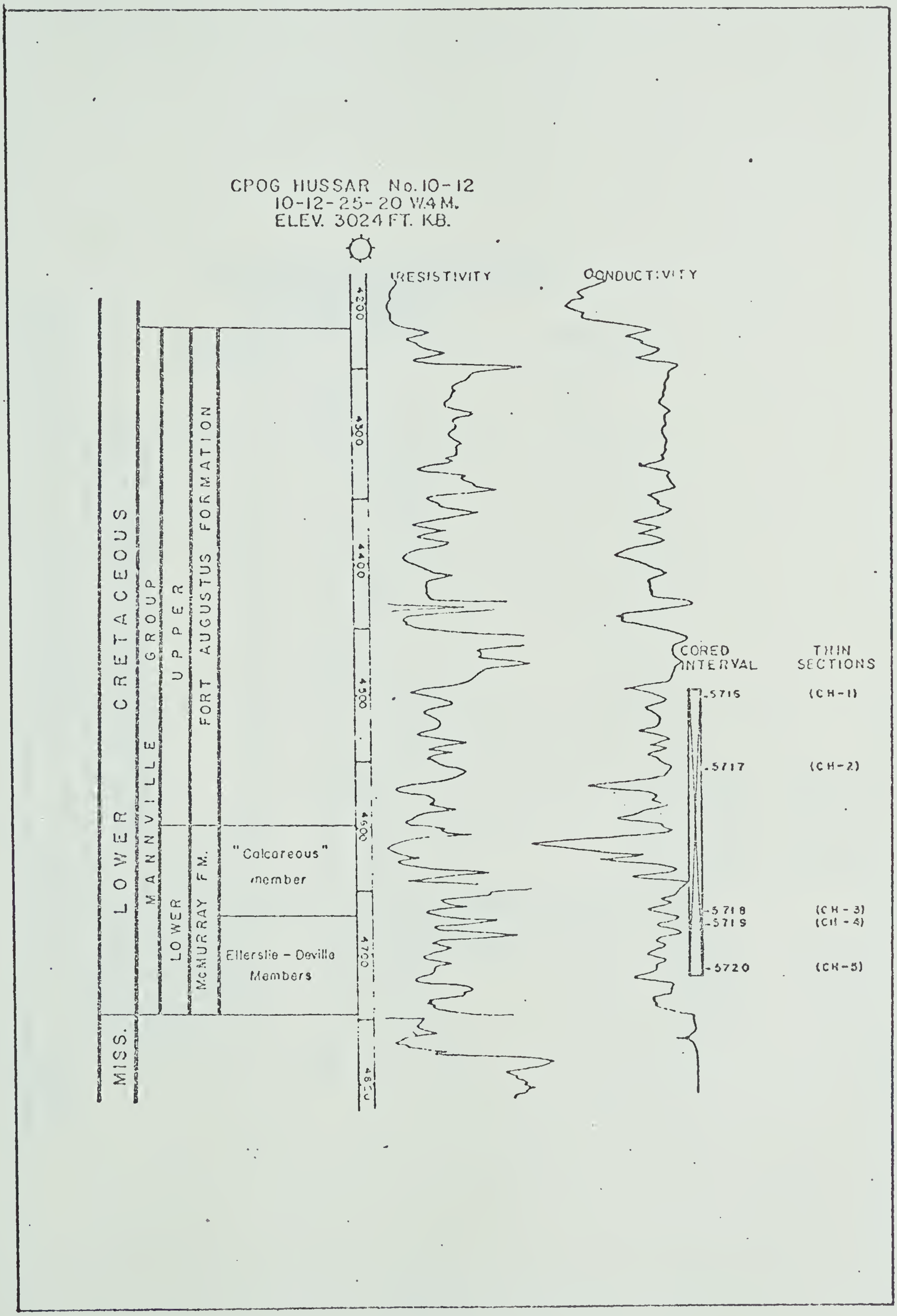
ELECTRIC LOGS OF WELLS WITH SAMPLE LOCATIONS

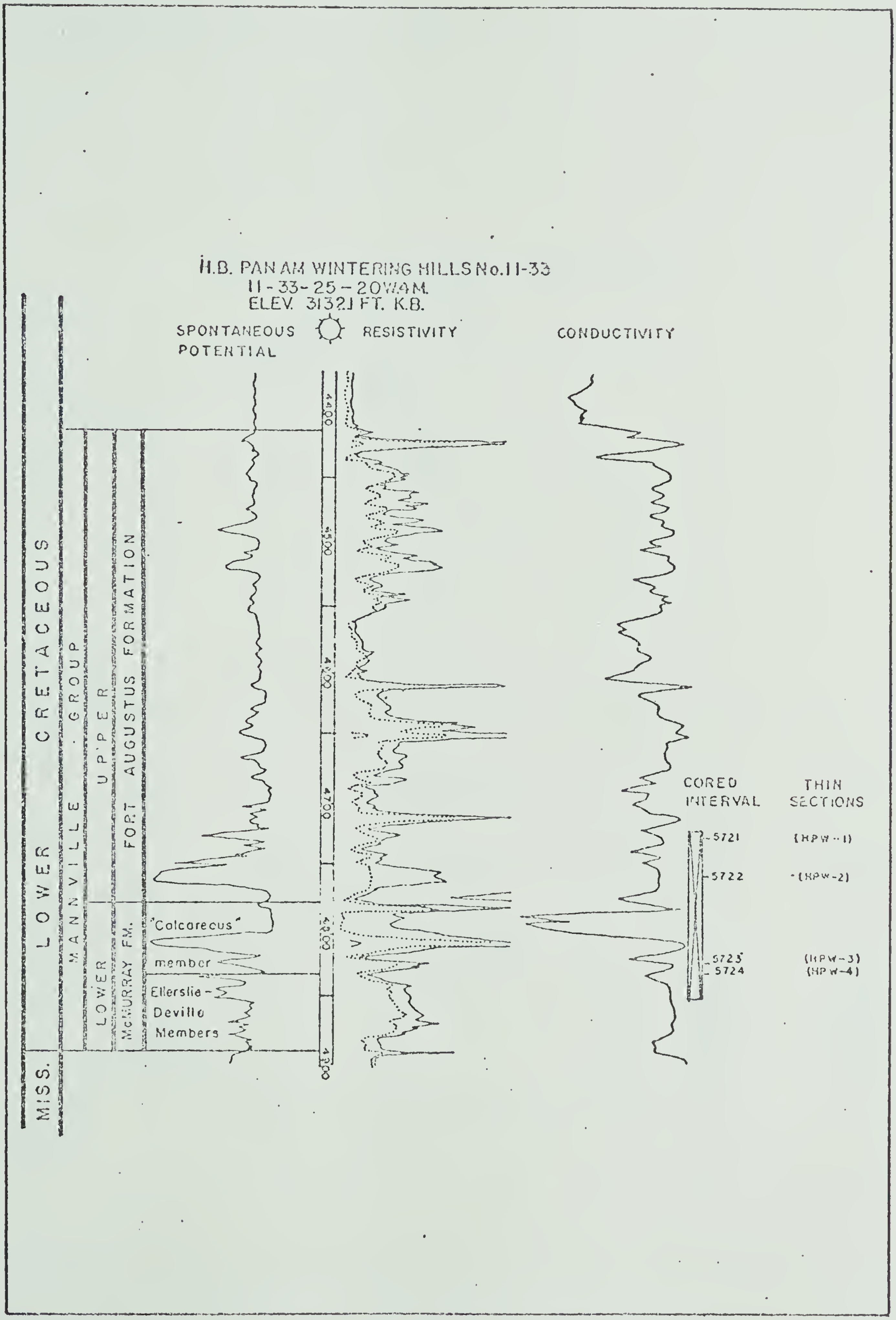

TENN. BD I HUSSAR 6-7
6 - 7 - 24 - 19 W.4M.
ELEV. 3030 FT. K.B.
SPONTANEOUS POTENTIAL
RESISTIVITY
CONDUCTIVITY
CORED INTERVALS
THIN SECTIONS
NOT LOGGED
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
LOWER
FORT AUGUSTUS FORMATION
McMURRAY FM.
"Calcareous" member
Ellerslie – Deville Members
MISS.
4100
4200
4300
4400
4500
4600
4700
5692
(HPH-1)
5693
5694
(HPH-2)
(HPH-3)
5695
(HPH-4)
5696
5697
(HPH-5)
(HPH-6)
5698
(HPH-7)
5699
5700
(HPH-8)
(HPH-9)
5701
(HPH-10)
5702
(HPH-11)

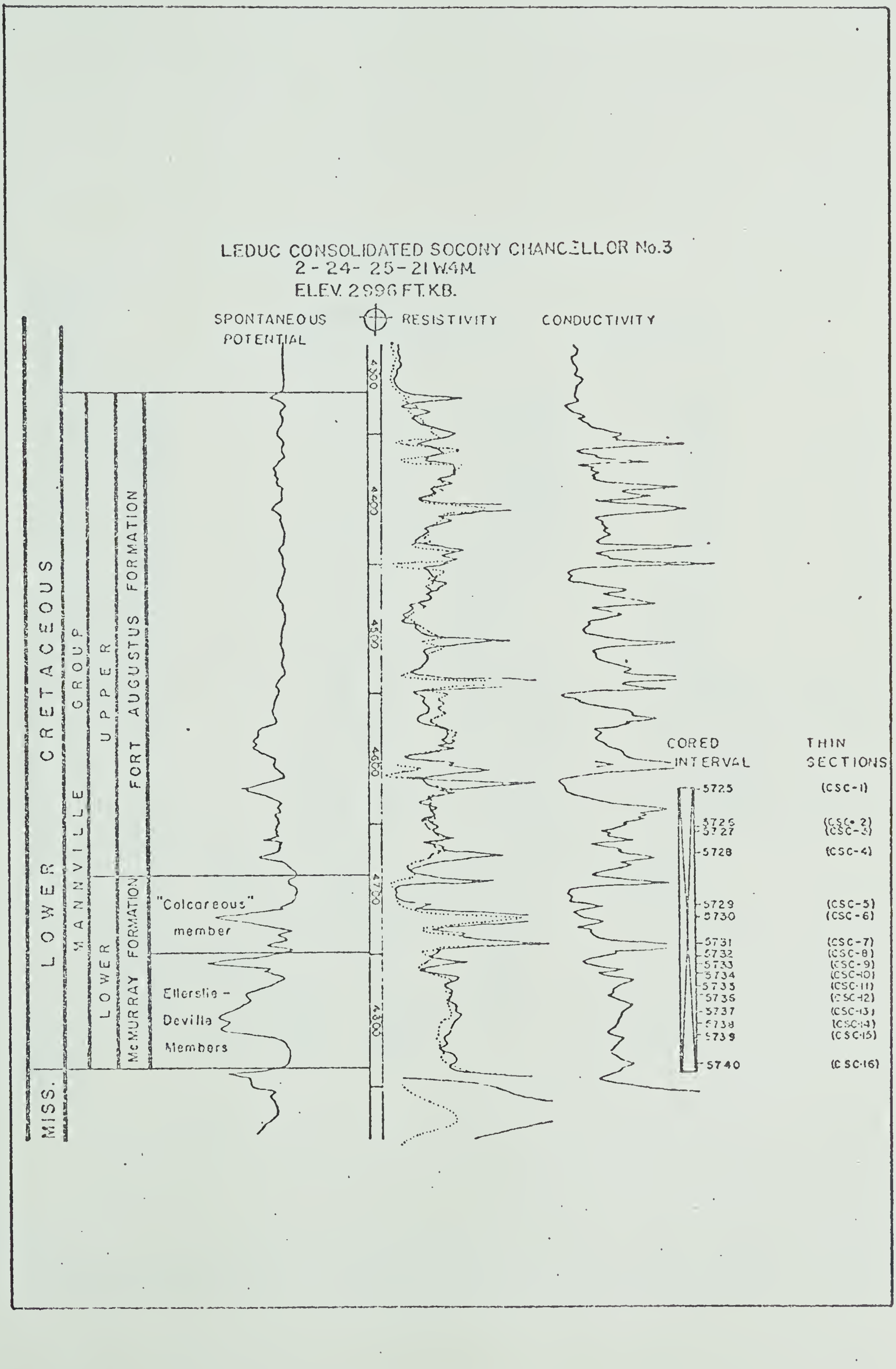

C.P.O.G. H. HUSSAR No. 11-33
11 - 33 - 24 - 20 W.4
ELEV. 2994 FT. K.B.
SPONTANEOUS POTENTIAL
RESISTIVITY
CONDUCTIVITY
LOWER CRETACEOUS
MISS.
MANNVILLE GROUP
UPPER
LOWER
FORT AUGUSTUS FORMATION
McMURRAY FORMATION
"Calcareous" member
Ellerslie – Deville Mbrs.
4300
4400
4500
4600
4700
4800
CORED INTERVAL
THIN SECTIONS
5703 (CHH-1)
5704 (CHH-2)
5705 (CHH-3)
5706 (CHH-4)
5707 (CHH-5)


JOE PHILLIPS HUSSAR No. 11-1
11-1-24-21 W.4 M.
ELEV. 2834.5 FT. K.B.
SPONTANEOUS POTENTIAL
RESISTIVITY
CONDUCTIVITY
LOWER CRETACEOUS
MISS.
MANNVILLE GROUP
UPPER
LOWER
FORT AUGUSTUS FM.
McMURRAY FM.
"Calcareous" mbr.
Ellerslie - Deville Members
4100
4200
4300
4400
4500
4600
CORED INTERVAL
THIN SECTIONS
5708
5709
5710
(JPH-1)
(JPH-2)
(JPH-3)

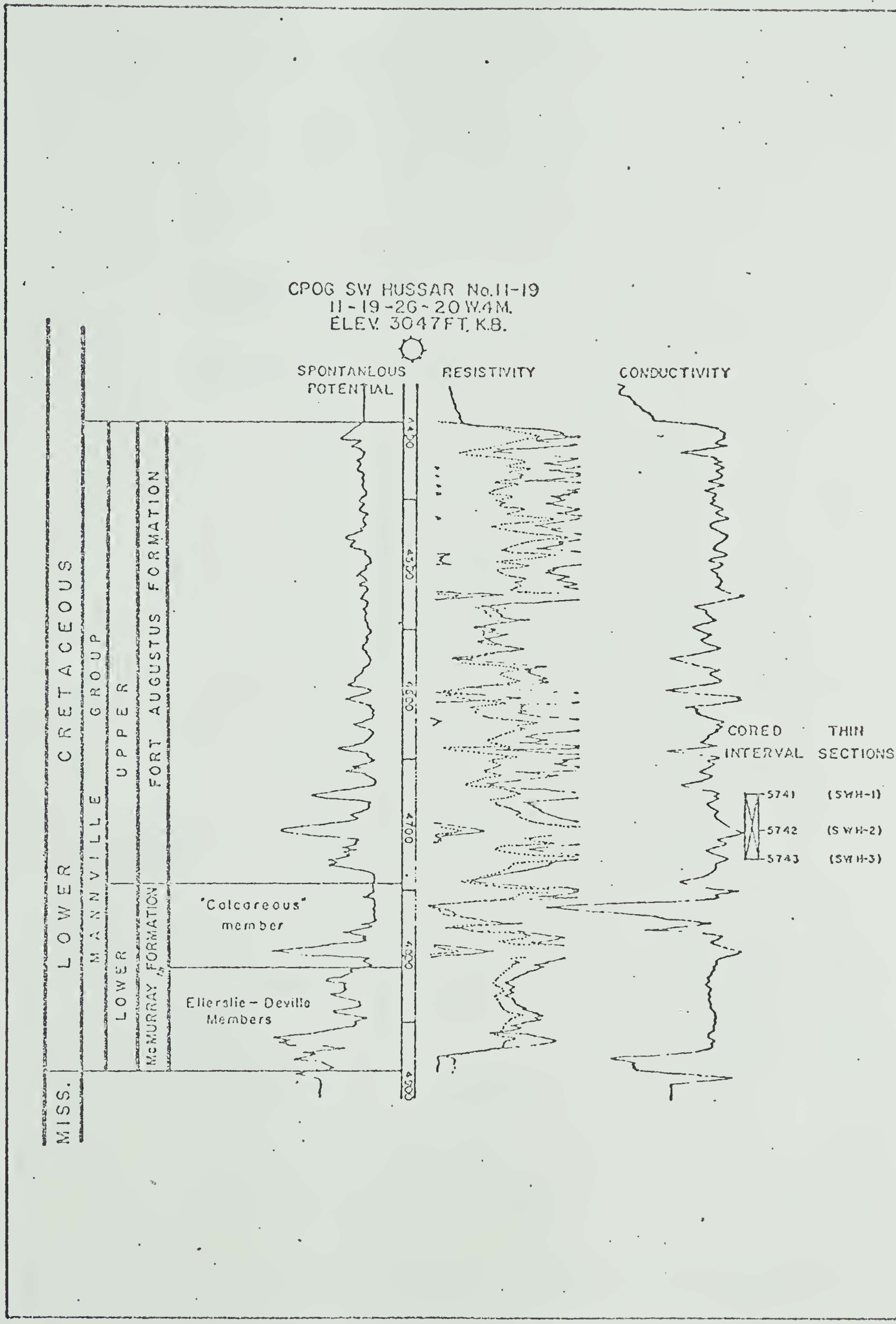

MOBIL C.P.R. PARFLESH No. 6-20
6-20-24-21 W4 M.
ELEV. 2922 FT. K.B.
RESISTIVITY
CONDUCTIVITY
LOWER CRETACEOUS
MISS.
MANNVILLE GROUP
UPPER
LOWER
FORT AUGUSTUS FORMATION
McMURRAY FM.
Calcareous member
Ellerslie-Deville Mbrs.
4300
4400
4500
4600
4700
CORED INTERVALS
THIN SECTIONS
5711
5712
5713
5714
5715
(MCP-1)
(MCP-2)
(MCP-3)
(MCP-4)
(MCP-5)

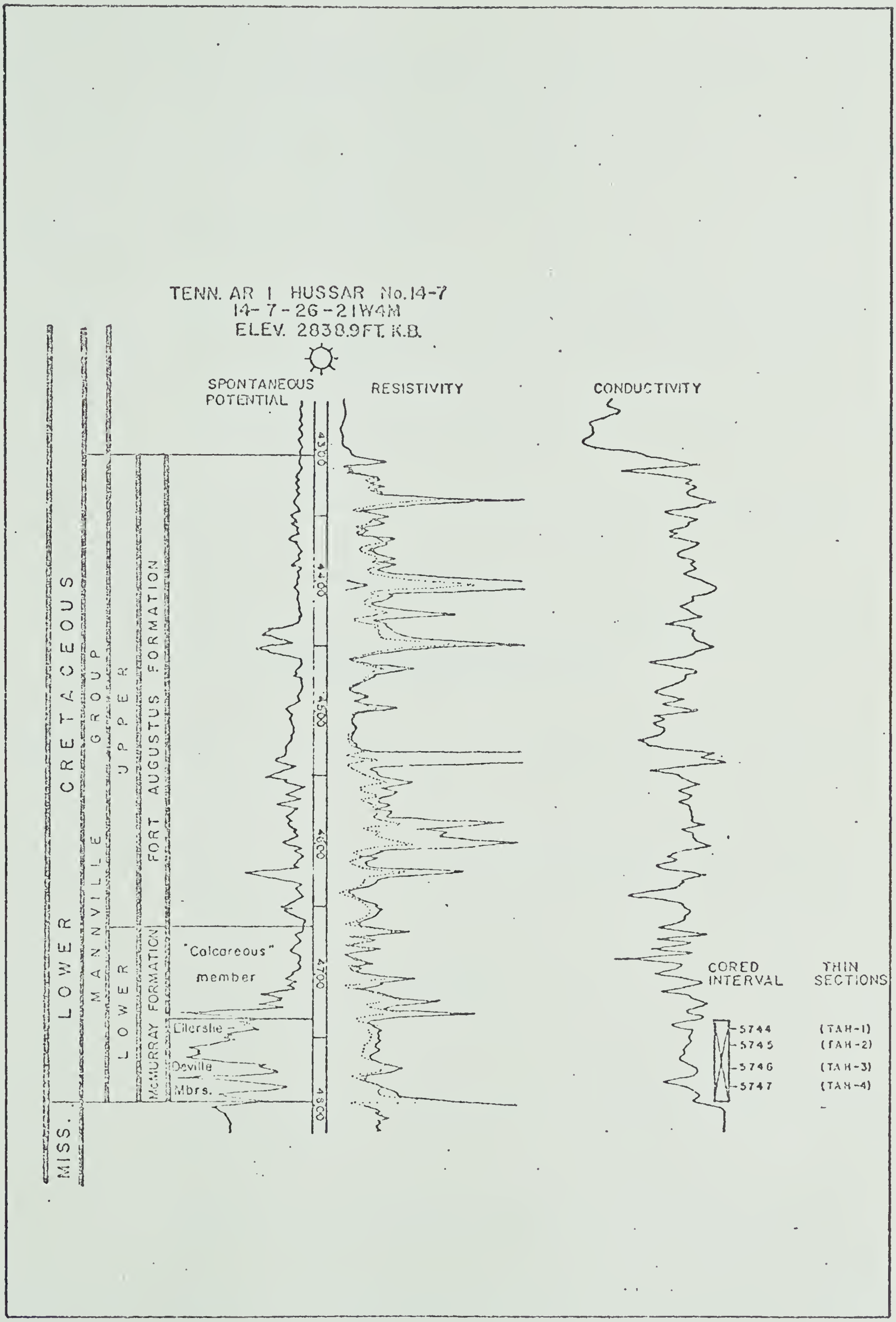

CPOG HUSSAR No.10-12
10-12-25-20 W.4 M.
ELEV. 3024 FT. KB.
RESISTIVITY
CONDUCTIVITY
LOWER CRETACEOUS
MISS.
MANNVILLE GROUP
UPPER
LOWER
FORT AUGUSTUS FORMATION
McMURRAY FM.
"Calcareous" member
Ellerslie - Deville Members
4200
4300
4400
4500
4600
4700
CORED INTERVAL
THIN SECTIONS
-5715 (CH-1)
-5717 (CH-2)
-5718 (CH-3)
-5719 (CH-4)
-5720 (CH-5)


H.B. PAN AM WINTERING HILLS No.11-33
11-33-25-20W4M.
ELEV. 3132.1 FT. K.B.
SPONTANEOUS POTENTIAL
RESISTIVITY
CONDUCTIVITY
LOWER CRETACEOUS
MISS.
MANNVILLE GROUP
UPPER
LOWER
FORT AUGUSTUS FORMATION
McMURRAY FM.
"Calcareous"
member
Ellerslie-
Deville
Members
4400
4500
4600
4700
4800
4900
CORED INTERVAL
THIN SECTIONS
5721
5722
5723
5724
(HPW-1)
(HPW-2)
(HPW-3)
(HPW-4)



LEDUC CONSOLIDATED SOCONY CHANCELLOR No.3
2-24-25-21 W4M
ELEV. 2996 FT. KB.
SPONTANEOUS POTENTIAL
RESISTIVITY
CONDUCTIVITY
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
LOWER
FORT AUGUSTUS FORMATION
McMURRAY FORMATION
"Calcareous" member
Ellerslie - Devilla Members
MISS.
4500
4600
4700
4800
CORED INTERVAL
THIN SECTIONS
5725 (CSC-1)
5726 (CSC-2)
5727 (CSC-3)
5728 (CSC-4)
5729 (CSC-5)
5730 (CSC-6)
5731 (CSC-7)
5732 (CSC-8)
5733 (CSC-9)
5734 (CSC-10)
5735 (CSC-11)
5736 (CSC-12)
5737 (CSC-13)
5738 (CSC-14)
5739 (CSC-15)
5740 (CSC-16)


CPOG SW HUSSAR No.11-19
11-19-26-20 W.4M.
ELEV. 3047 FT. K.B.
SPONTANEOUS POTENTIAL
RESISTIVITY
CONDUCTIVITY
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
LOWER
FORT AUGUSTUS FORMATION
McMURRAY FORMATION
"Calcareous" member
Ellerslie - Deville Members
MISS.
CORED INTERVAL
THIN SECTIONS
5741
(SWH-1)
5742
(SWH-2)
5743
(SWH-3)
4700



TENN. AR I HUSSAR No.14-7
14-7-26-21W4M
ELEV. 2838.9FT. K.B.
SPONTANEOUS POTENTIAL
RESISTIVITY
CONDUCTIVITY
4300
4400
4500
4600
4700
4800
LOWER CRETACEOUS
MISS.
MANNVILLE GROUP
UPPER
LOWER
FORT AUGUSTUS FORMATION
McMURRAY FORMATION
"Calcareous" member
Ellerslie
Ostracod
Mbrs.
CORED INTERVAL
THIN SECTIONS
5744
5745
5746
5747
(TAH-1)
(TAH-2)
(TAH-3)
(TAH-4)

APPENDIX C

CORE DESCRIPTIONS

Tenn BD 1 Hussar No. 6-7

Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M

Elevation 3030 feet K.B.

Core 2	4205-45 Recovery 40'
2'10"	SHALE, greenish grey to light olive grey, soft, very silty, micaceous, carbonaceous, becomes rubbly towards base, minor scattered pyrite nodules. Distinct bottom contact.
0'8"	SHALE, greyish black to black, micaceous with irregular thin silty laminae, abundant coalified plant fragments.
3'9"	SHALE, greenish grey to light olive grey, soft, very silty, micaceous, sideritic in part, rubbly, minor slickensides. Distinct bottom contact.
1'3"	SILTSTONE, medium grey to medium dark grey, micaceous, pyritic, flecked with carbonaceous material, plant remains scattered throughout basal 1'.
0'6"	SHALE, greenish grey to light olive grey, soft very silty, micaceous, friable, slightly sideritic, rubbly, with minor slickensides.
2'7"	SHALE, medium grey to medium dark grey, soft, micro-micaceous pyritic, with abundant plant fragments, minor slickensides.
0'6"	SHALE, as at 0'6" above.
1'11"	SILTSTONE, as at 1'3" above.
5'2"	SHALE, dark grey, silty, very carbonaceous to coaly with much carbonized plant material along bedding planes, abundant pyrite nodules.
0'10"	SHALE, greenish grey to olive grey, soft, silty, micaceous, abundant carbonized plant remains, minor slickensides.
1'2"	SHALE, greenish grey to light olive grey, very silty, micaceous, pyritic, minor iron staining with abundant bituminous streaks.
3'4"	SILTSTONE, medium grey to greenish grey, micaceous, pyritic,

	iron stained, flecked with carbonaceous material.
3'2"	SHALE, light olive grey, micaceous, abundant iron-staining flecked with carbonaceous material.
0'8"	SHALE, medium grey to medium dark grey, soft, silty, micromicaceous, carbonaceous with a few plant fragments.
1'7"	SHALE, as at 1'2" above, with scattered plant fragments and minor slickensides.
1'5"	SILTSTONE, as at 3'4" above, with minor plant fragments.
3'2"	SANDSTONE, very fine grained to SILTSTONE, light greenish grey, micaceous and carbonaceous along bedding planes with minor plant fragments.
5'6"	SILTSTONE, greenish grey to medium light grey, with scattered irregular shaly laminae, micaceous and carbonaceous along bedding planes, becoming more shaly in basal 1'. Pyrite nodules common.
Core 3	4370-4420 Recovery 50'
0'5"	SHALE, light olive, very calcareous, argillaceous, carbonaceous.
7'1"	SILTSTONE, medium light grey to medium grey, micaceous, flecked with carbonaceous material, sideritic in part. Minor nodular pyrite.
0'6"	SHALE, medium dark grey to dark grey, silty, micromicaceous, carbonaceous with a few plant fragments.
0'6"	SILTSTONE, as at 7'1" above.
2'7"	SHALE, as at 0'6" above.
6'5"	SHALE, medium dark grey, silty, micaceous, irregularly interbedded with thin laminae of SILTSTONE, light grey, micaceous and carbonaceous along bedding planes, with abundant plant remains (stem, leaves, etc.) and large pyrite nodules.
2'3"	SHALE, medium grey to medium dark grey, micaceous, carbonaceous, abundant bituminous material along bedding.

5'7"	COAL, fractured, with abundant pyrite.
1'2"	SHALE as at 2'3" above, with irregular silty laminae and abundant slickensides, becoming blocky and rubbly towards base.
2'6"	SILTSTONE, medium grey to medium dark grey, iron-stained, micaceous and carbonaceous along bedding planes, minor bituminous streaks, abundant plant fragments. Pyrite nodules common.
2'0"	SHALE, medium dark grey to dark grey, silty, micromicaceous carbonaceous with abundant plant fragments, scattered bituminous material. Large pyrite nodules common.
10'3"	SILTSTONE, medium grey, micaceous and carbonaceous along bedding planes with abundant scattered plant remains, with irregular shaly laminae in basal 3'. Nodular pyrite common.
8'9"	SHALE, medium dark grey to dark grey, silty, micromicaceous pyritic, sideritic in part, with abundant plant fragments and scattered bituminous material with irregular thin beds (up to 3") of SILTSTONE, medium grey, micaceous and carbonaceous along bedding planes.
Core 4	4506-56 Recovered 50'
6'10"	SILTSTONE, light grey to medium grey, "salt and pepper", micaceous and carbonaceous along bedding planes, becoming shaly towards base. Pyrite nodules common.
4'2"	SANDSTONE, light olive grey, fine to medium grained, quartz "salt and pepper", subangular to subrounded, well sorted, very minor micaceous and carbonaceous material along bedding planes.
6'5"	SANDSTONE, light olive grey, fine to very fine grained, quartz, "salt and pepper", subangular, fair sorting, with abundant micaceous and carbonaceous material along bedding planes, slightly calcareous, occasional dark grey shaly partings. Large pyrite nodules common.
8'7"	SILTSTONE, medium dark grey to dark grey, micaceous, carbonaceous, with irregular mottlings, laminae and thin

	interbeds of SHALE, dark grey with scattered bituminous material. Pyrite nodules common. Minor slickensides.
4'10"	SHALE, medium grey to medium dark grey, micromicaceous, carbonaceous, with irregular scattered laminae of SILTSTONE, light grey, quartz. Nodular and disseminated pyrite common. Distinct bottom contact.
8'2"	SANDSTONE, as at 4'2" above, with abundant plant fragments in basal 1', associated with disseminated pyrite.
3'0"	SHALE, medium dark grey, micromicaceous, carbonaceous, minor bituminous material. Nodular and disseminated pyrite common.
3'3"	SHALE, greenish grey to light olive grey, calcareous, micaceous, few small shaly pebbles (?) Abundant scattered pyrite nodules.
2'0"	SHALE, dark grey, soft, calcareous, micromicaceous, carbonaceous, very fossiliferous.
2'9"	SHALE, as at 3'3" above.
Core 5	4556-4606 Recovery 40'
5'6"	SHALE, light olive grey-brown, very calcareous, micaceous, pyritic, fossiliferous (pelecypods, gastropods), with minor scattered bituminous veins.
4'2"	SILTSTONE, light grey to light olive grey, micaceous, calcareous, minor bituminous streaks. Nodular and disseminated pyrite common. Sharp basal contact.
4'6"	SHALE, dark grey to medium dark grey, micromicaceous with irregular very thin silty laminae, minor slickensides.
2'6"	SILTSTONE, medium light grey to light olive grey, micaceous, minor scattered bituminous material, mottled, sideritic and pyritic in part.
3'6"	SILTSTONE, light olive grey, calcareous, micaceous, pyritic.
1'0"	SANDSTONE, very fine grained to SILTSTONE, medium light grey to medium dark grey, "salt and pepper", calcareous, micaceous, minor scattered carbonaceous material,

	fossiliferous (pelecypods, gastropods). One small siderite nodule.
3'6"	SHALE, light olive grey to dark grey, micromicaceous, with irregular very thin dark grey laminae, calcareous in part, minor bituminous material. Disseminated pyrite common along fractures.
5'2"	SANDSTONE, very fine grained to SILTSTONE, light grey to light olive grey, calcareous, micaceous, minor carbonaceous material. Nodular and disseminated pyrite common.
0'8"	SHALE, light grey to medium grey, silty, micromicaceous with scattered carbonaceous material. Distinct contact at base.
3'0"	SANDSTONE, as at 5'2" above with abundant nodular pyrite and minor bituminous impregnations.
1'8"	SANDSTONE, very fine grained to SILTSTONE, light olive grey, calcareous, micaceous, iron-stained, minor siderite nodules, very minor pyrite nodules, becomes olive grey towards base of unit. Distinct contact at base.
0'6"	SHALE, dark grey to greyish black, micaceous, silty, carbonaceous with a few plant fragments, minor worm burrows (?) filled with calcite.
2'10"	LIMESTONE, olive grey, oolitic, argillaceous, carbonaceous with scattered plant fragments and bituminous impregnations, very minor scattered veins, filled with pyrite. Unit is olive grey to dark grey in basal 6" with a sharp basal contact.
1'1"	SANDSTONE, light olive grey to light grey, fine to medium grained, quartz, well sorted, subangular to subrounded, silty, calcareous, minor pyrite. Fair to poor porosity.
0'5"	SHALE, as at 0'6" above, pyritic.
Core 6	4606-4651 Recovery 44'
0'4"	SILTSTONE, medium light grey to medium grey, micaceous, pyritic, with minor bituminous streaks.
3'4"	SANDSTONE, light olive grey, fine to medium grained, quartz,

	friable, subangular to subrounded, well sorted, good porosity.
2'8"	SANDSTONE, very fine grained to SILTSTONE, light olive grey, quartz, with abundant scattered chert pebbles in siliceous matrix, hard, dense, minor slickensides.
0'3"	SANDSTONE, as at 3'4" above.
9'3"	SANDSTONE, as at 2'8" above.
5'2"	SANDSTONE, very light grey to yellowish grey, fine to medium grained, quartz with scattered chert grains, friable, subangular to subrounded, well sorted, good porosity.
6'1"	SANDSTONE, as immediately above with abundant shaly partings.
9'6"	SANDSTONE, as at 5'2", silty with minor shaly partings, very porous and in part lightly oil stained.
7'5"	SANDSTONE, as at 6'1", very porous and in part lightly oil stained, minor scattered chert pebbles in basal 1'.
Core 7	4651-4701 Recovery 50'
5'6"	SANDSTONE, as at 7'5" in base of Core 6.
1'2"	SHALE, olive grey to light greyish green, waxy, containing abundant angular quartz and chert grains and pebbles.
3'4"	SANDSTONE, light grey to light greenish grey, very fine to fine grained, quartz, subangular to subrounded, calcareous, argillaceous, with irregular silty laminae, micaceous and carbonaceous along bedding planes in basal 1'. Minor iron staining.
4'8"	SANDSTONE, very fine grained to SILTSTONE, light greenish grey, quartz, waxy, sideritic in part, minor slickensides.
7'10"	SANDSTONE, light yellowish brown to dark brown, very fine to fine grained, quartz with chert grains in siliceous matrix, thin irregular shaly partings, hard dense.

8'6"	SANDSTONE, very fine grained to SILTSTONE, light greenish grey, quartz, waxy, sideritic in part, slightly micaceous. Abundant scattered pyrite nodules in basal 2'.
13'7"	SANDSTONE, light grey to light greenish grey, fine to medium grained quartz, with abundant scattered chert pebbles in siliceous matrix, minor scattered shaly partings, slickensides common. Abundant pyrite nodules.
5'5"	SHALE, light greyish green, containing abundant angular quartz and chert grains and large angular chert fragments. Interval highly brecciated. Nodular pyrite common.

CPOG H Hussar No. 11-33

Lsd. 11, Sec. 33, Twp. 24, Rge. 20, W4M

Elevation 2994 feet K.B.

Core 1	4544-4609 Recovery 60'
3'5"	SHALE, medium grey to medium dark grey, micaceous, calcareous, with minor scattered bituminous material.
5'3"	SHALE, greyish black, soft, micaceous, scattered bituminous streaks, minor slickensides, nodular pyrite common.
2'4"	SHALE, medium dark grey, soft, micromicaceous, slightly silty, plant fragments common, minor bituminous impregnations, sideritic carbonaceous, pyrite nodules common. Thin ($\frac{1}{4}$") coal band at base.
2'9"	SILTSTONE, light grey, micaceous, sideritic, abundant scattered pyrite nodules (up to $\frac{1}{4}$" dia.).
2'3"	SANDSTONE to SILTSTONE, light olive grey to olive grey, "salt and pepper", calcareous, micaceous, silty, sideritic.
3'11"	SANDSTONE, light to medium grey, very fine to fine grained, "salt and pepper", subangular to subrounded, poorly sorted, micaceous, calcareous, sideritic, with very fine irregular shaly laminae at base. Poor porosity.
1'7"	SHALE, medium dark grey to dark grey, soft, micromicaceous, flecked with carbonaceous material, nodular pyrite common. Disturbed zone, 6" from base, associated with slickensides and coalified material.
3'0"	SHALE, medium dark grey to dark grey, soft, micaceous, carbonaceous, with scattered laminae of SILTSTONE, light grey, "salt and pepper", carbonaceous showing horizontal and cross bedding.
1'6"	SHALE, medium dark grey, soft, micromicaceous, slightly silty, pyritic, with thin (1"-2") siderite bands.
5'0"	SHALE, medium dark grey to dark grey, soft, micromicaceous, flecked with carbonaceous material, pyrite nodules (up to $\frac{1}{2}$" dia.) common. Slickensided throughout.

4'0"	SHALE, medium grey to light olive grey, soft, micro-micaceous, carbonaceous flecks, bituminous impregnations, pyrite nodules (up to $\frac{1}{2}$' dia.) common.
1'6"	SILTSTONE to SANDSTONE, greenish grey to dark greenish grey, very fine to fine grained, "salt and pepper", subangular to subrounded, poorly sorted, micaceous, sideritic, slightly silty, scattered pyrite nodules. Poor porosity.
9'6"	SANDSTONE, light yellowish grey, very fine grained, quartz, "salt and pepper", subangular to subrounded, fairly well sorted, micaceous and carbonaceous along bedding planes, sideritic, with thin laminae SHALE, dark grey, micaceous, carbonaceous, abundant scattered pyrite, showing cross bedding towards base of unit. Fair porosity.
1'2"	SHALE, dark grey, soft, micromicaceous, with abundant plant fragments, minor pyrite.
1'7"	As above, disturbed zone associated with slickensides.
7'2"	SHALE, medium grey to medium dark grey, micromicaceous in part, irregularly laminated with SILTSTONE, light grey, "salt and pepper", with a highly contorted zone (2' thick) 2' from base. Abundant carbonaceous material. Nodular and disseminated pyrite common.
2'8"	SANDSTONE, light to medium grey, very fine to fine grained, quartz, "salt and pepper", subangular to subrounded, fair sorting, micaceous and carbonaceous along bedding planes, sideritic, silty, nodular pyrite common. Poor porosity.
1'5"	SHALE, medium dark grey, soft, micromicaceous, bituminous impregnations, plant fragments and pyrite nodules common.

Joe Phillips Hussar No. 11-1

Lsd. 11, Sec. 1, Twp. 24, Rge. 21, W4M

Elevation 2834.5' K.B.

Core 1	4410-4471 Recovery 59'2"
7'2"	SHALE, medium dark grey, silty, micaceous, minor bituminous streaks, with thin irregular, silty laminae. Highly disrupted zone (1' thick) $3\frac{1}{2}$' from top, with abundant pyrite nodules.
3'4"	SHALE, as above with few thin laminae towards base of SANDSTONE, light grey, very fine to fine grained, "salt and pepper", angular to subangular.
13'6"	SANDSTONE, light grey, very fine to fine grained, "salt and pepper", angular to subangular, poorly sorted, sideritic, irregularly, laminated with SILTSTONE, dark grey, micaceous and carbonaceous along bedding planes. Nodular pyrite common. Poor porosity.
2'2"	SHALE, medium dark grey, silty, micromicaceous, pyritic, irregularly interbedded with thin laminae of SILTSTONE, light grey, "salt and pepper", sideritic, towards base.
1'6"	SANDSTONE, as at 13'6" above.
1'2"	SHALE, medium dark grey, rubbly, micaceous, sideritic, with irregular fine silty laminae. Highly fractured at base with abundant nodular and disseminated pyrite.
4'2"	SANDSTONE, light grey, fine to medium grained, "salt and pepper", subangular to subrounded, fair sorting, sideritic, micaceous, carbonaceous with scattered fine coaly partings.
2'5"	SHALE, medium dark grey, soft, silty, pyritic few thin laminae and thin irregular lentils of SANDSTONE, as at 4'2" above, rare shaly pebbles.
23'9"	SANDSTONE, light olive grey, fine to medium grained, "salt and pepper", subangular to subrounded, fair to poor sorting, micaceous, sideritic, with minor thin coaly partings. Poor porosity.

Core 2	4471-4527 Recovery 56'
8'0"	SANDSTONE as in basal 23'9" of Core 1, with minor pyrite and thin carbonaceous bands in basal 1'.
3'7"	SANDSTONE, olive grey, medium grained, "salt and pepper", subangular to subrounded, fair to poor sorting, micaceous, and carbonaceous along bedding planes becoming more carbonaceous towards base of unit.
6'7"	SANDSTONE, as above, with shale pebble inclusions and chert pebbles, pyritic in basal 1'.
4'6"	SILTSTONE, light grey to medium light grey, sideritic, carbonaceous with irregular shaly laminae in top 3" of unit.
2'5"	SHALE, dark grey to greyish black, soft, becoming increasingly carbonaceous and pyritic towards base, minor calcite-filled inclusions.
4'2"	SILTSTONE, light olive grey, with abundant scattered carbonaceous material, and irregular dark grey shaly laminae.
11'6"	SHALE, light greyish green to bluish green, waxy, calcareous, containing abundant angular quartz and chert grains and pebbles, pyrite very abundant. Interval highly sheared, slickensides common.
3'1"	LIMESTONE, very light grey, hard, sideritic, with irregular thin green shaly laminae.
1'0"	SHALE, as at 11'6" above.
3'0"	LIMESTONE, as at 3'1" above.
8'2"	SHALE, pale yellowish green, calcareous, with irregular silty, laminae, minor vertical fractures filled with calcite.

Mobil CPR Parflesh No. 6-20

Lsd. 6, Sec. 20, Twp. 24, Rge. 21, W4M

Elevation 2922 feet K.B.

Core 1	4627-4687 Recovery 58'
4'2"	SILTSTONE, medium dark grey to dark grey, micaceous, flecked with carbonaceous material, minor siderite, abundant nodular pyrite.
2'2"	SHALE, medium grey to medium dark grey, silty, micro-micaceous, carbonaceous flecks, minor slickensides.
2'11"	SILTSTONE, light olive grey, micaceous, flecked with carbonaceous material, abundant siderite, hard.
3'9"	SANDSTONE, to SILTSTONE, light olive grey, very fine grained, "salt and pepper", silty, banded and thinly inter-bedded with SHALE, medium dark grey, micaceous and carbonaceous along bedding planes.
3'11"	SHALE, greyish black, silty, micromicaceous coaly, disrupted and pyritized at top of unit.
1'3"	SHALE, olive grey to light olive grey, silty, micromicaceous, flecked with carbonaceous material, scattered bituminous material.
4'10"	SILTSTONE, light olive grey, micaceous, carbonaceous flecks, with fine irregular dark grey shaly laminae in basal 1'.
1'2"	SANDSTONE, light olive grey, very fine to medium grained, "salt and pepper", subangular to subrounded, fair to poor sorting, silty, micaceous, carbonaceous. Poor porosity.
0'9"	SILTSTONE, medium dark grey, micaceous, carbonaceous with scattered laminae of SHALE, medium grey, silty, micro-micaceous, carbonaceous.
1'1"	SANDSTONE as at 1'2" above.
5'9"	SHALE, dark grey, slightly silty, micaceous, interbeds and fine irregular laminae of SILTSTONE, light grey, "salt and

pepper", minor bituminous streaks and iron-staining.

1'3"	SILTSTONE, medium dark grey to dark grey, silty, micaceous carbonaceous, irregularly interbedded with SILTSTONE to SANDSTONE, light olive grey, very fine to medium grained, "salt and pepper", becoming very silty towards base. Nodular pyrite common.
5'4"	SANDSTONE, medium light grey to medium grey, very fine to fine grained, "salt and pepper", subangular to subrounded, fair to poor sorting, calcareous, micaceous, sideritic and carbonaceous in part. Poor porosity.
7'5"	SANDSTONE, as above, medium light grey, micaceous and carbonaceous along bedding planes, scattered plant fragments, pyrite nodules common. Poor porosity.
4'9"	SHALE, dark grey to medium dark grey, silty, irregularly interbedded with SILTSTONE, light grey to medium light grey, "salt and pepper", sideritic, micaceous and carbonaceous along bedding planes, showing horizontal and cross bedding. Pyrite nodules common.
0'4"	SILTSTONE, medium grey to medium dark grey, silty, micromicaceous, flecked with carbonaceous material.
2'5"	SHALE, medium grey to medium dark grey, fairly well bedded to blocky, with irregular thin silty bands and laminae calcareous, pyritic, very fossiliferous (pelecypods and gastropods), scattered carbonaceous flecks.
4'9"	SHALE to SILTSTONE, greenish grey, very calcareous, argillaceous, micromicaceous, few carbonaceous plant fragments and minor scattered bituminous impregnations.
Core 2	4710-4751 Recovery 40'5"
1'11"	SHALE, medium dark grey to dark grey, calcareous, micromicaceous, pyritic irregularly laminated with light olive grey silty laminae. Thin bed ($2\frac{1}{2}$") LIMESTONE, light grey to medium light grey, very argillaceous, 9" from top of unit. Very fossiliferous at base.
4'2"	SILTSTONE to SANDSTONE, light olive grey, very fine grained, quartz, subangular to subrounded, fairly well sorted, sideritic,

	micaceous and carbonaceous along bedding planes. Poor porosity.
0'5"	SHALE, dark grey, argillaceous, sideritic with abundant, coalified plant fragments.
1'4"	SILTSTONE, light olive grey, micaceous, carbonaceous, calcareous, fossiliferous (pelecypods, gastropods).
5'2"	LIMESTONE, medium light grey to medium grey, finely crystalline, argillaceous, abundant fossil remains. One $\frac{1}{2}$" band SHALE, dark grey, silty, occurs 3'3" from top of interval.
3'3"	SILTSTONE, light grey to medium grey, micaceous, calcareous, argillaceous.
9'8"	SHALE, medium dark grey to greyish black, micromicaceous, calcareous, with scattered fine irregular silty laminae, very fossiliferous (pelecypods, gastropods, ostracods), worm burrows.
5'0"	SILTSTONE, light grey to medium light grey micaceous, calcareous, pyritic, fossiliferous, with vertical fracture (1'5" long) filled with calcite.
1'4"	SHALE, medium dark grey to dark grey, very calcareous, argillaceous, micaceous, abundant pyrite.
3.5"	SHALE, dark grey to greyish black, micromicaceous, carbonaceous, very fossiliferous (pelecypods, gastropods, ostracods), with scattered irregular thin silty laminae.
4'9"	SILTSTONE, medium grey to medium light grey, micro-micaceous, calcareous, very fossiliferous, (pelecypods, gastropods, ostracods) minor carbonaceous material.

CPOG Hussar No. 10-12

Lsd. 10, Sec. 12, Twp. 25, Rge. 20, W4M

Elevation 3024' K.B.

Core 1	4499-4559 Recovery 59'5"
1'0"	SILTSTONE, light grey to medium light grey, "salt and pepper", micaceous, sideritic carbonaceous in part, fine irregular laminae of SHALE, dark grey, silty, micaceous, carbonaceous along bedding planes.
0'3"	SHALE, medium grey to medium dark grey, silty, micaceous, pyritic, sideritic, few plant remains.
1'9"	SHALE to SILTSTONE, medium grey to medium light grey, micaceous, sideritic, carbonaceous along bedding planes.
1'6"	SILTSTONE, light grey to medium light grey, "salt and pepper", micaceous, sideritic, carbonaceous along bedding planes.
3'6"	SANDSTONE, light grey, very fine to fine grained, "salt and pepper", subangular to subrounded, fair sorting, slightly silty, micaceous, sideritic. Poor porosity.
2'10"	SILTSTONE, light grey to medium light grey, "salt and pepper", micaceous, sideritic, carbonaceous along bedding planes, abundant coalified plant fragments, minor slickensiding at base.
0'2"	SHALE, black, coaly.
2'0"	SHALE, medium grey to medium dark grey, silty, micaceous, carbonaceous, scattered laminae of SILTSTONE, light grey, thin (3/4") coaly band at base.
0'5"	SHALE, medium grey to medium dark grey, silty, micaceous, carbonaceous, with minor slickensiding.
0'11"	SILTSTONE, medium light grey, quartz, micaceous, carbonaceous, sideritic, irregularly laminated with SHALE, dark grey, micromicaceous, carbonaceous.

0'7"	SILTSTONE, medium grey, micaceous, sideritic, carbonaceous, scattered poorly preserved ostracod remains.
0'10"	SHALE, medium grey to medium dark grey, silty, micaceous, carbonaceous with minor slickensiding.
1'4"	SHALE, as above but not slickensided.
3'0"	SILTSTONE, as above.
0'4"	SHALE, medium grey to dark grey, soft silty, carbonaceous.
8'8"	SHALE, medium grey to medium dark grey, micaceous, carbonaceous, waxy in part, with thin scattered laminae of SILTSTONE, light grey, quartz, becoming increasingly carbonaceous, pyritic towards base with abundant plant fragments. One siderite band, 3" thick occurs at base.
1'10"	SHALE, medium dark grey, waxy, micromicaceous, carbonaceous.
2'4"	SILTSTONE, light grey, quartz, micaceous, slightly carbonaceous.
2'6"	SANDSTONE, light olive grey, fine to medium grained, "salt and pepper", subangular to subrounded, fair sorting, micaceous, poor porosity.
7'10"	SILTSTONE, light grey to medium light grey, "salt and pepper", micaceous, sideritic, carbonaceous flecks, irregularly laminated, with SHALE, medium dark grey to dark grey, micaceous, sideritic, scattered coalified plant fragments. Shows horizontal and cross bedding.
0'9"	SHALE, dark grey to black, waxy, fissile, pyritic.
2'2"	SHALE, dark grey to medium dark grey, silty, micaceous grading to SILTSTONE, medium dark grey, carbonaceous.
1'3"	SANDSTONE, light grey to medium light grey, "salt and pepper", subangular to subrounded, fair sorting, micaceous, poor porosity.
0'6"	SILTSTONE, light grey, quartz, micaceous, sideritic, finely laminated with SHALE, medium dark grey, bituminous streaks, pyritic.

1'11"	SILTSTONE, light olive grey, carbonaceous, micaceous, few shaly laminae with minor bituminous streaks.
3'10"	SHALE, medium dark grey to dark grey, micaceous, sideritic, slightly waxy in part, abundant coalified plant fragments, with SILTSTONE, light grey, exhibiting minor cross bedding.
1'2"	SANDSTONE, light olive grey, fine to medium grained, "salt and pepper", subangular to subrounded, fair to poor sorting, argillaceous, fair to poor porosity.
0'4"	SILTSTONE, light grey, quartz, argillaceous, micaceous, sideritic.
3'11"	SANDSTONE, very fine grained to SILTSTONE, light grey to medium light grey, "salt and pepper", micaceous, sideritic, carbonaceous in part, irregularly laminated with SHALE, dark grey micaceous, carbonaceous along bedding planes, few plant fragments and siderite nodules towards base.
Core 2	4559-4619 Recovery 60'
2'3"	As in basal 3'11" of Core 1.
1'8"	SANDSTONE, very fine grained to SILTSTONE, light olive grey, "salt and pepper", slightly carbonaceous with very fine laminae of SHALE, medium dark grey, micaceous.
2'5"	SILTSTONE, medium light grey to medium grey, micaceous, sideritic, carbonaceous, irregularly laminated with SHALE, medium dark grey, micaceous.
0'2"	SHALE, dark grey to black, coaly.
1'4"	SHALE, medium light grey to medium grey, with abundant coalified plant fragments, large pyrite nodules common.
1'5"	SHALE, greenish grey, micaceous, argillaceous, calcareous, scattered bituminous streaks.
4'0"	SILTSTONE, medium light grey to medium grey, micaceous, sideritic, carbonaceous, irregularly laminated with SHALE, light grey, calcareous.
0'3"	SHALE, greenish grey, soft, micaceous, carbonaceous, bentonitic.

1'7"	SHALE to SILTSTONE, medium grey to medium dark grey, micaceous, sideritic, few plant fragments, minor disseminated and nodular pyrite.
7'6"	SHALE, medium dark grey to dark grey, argillaceous, micaceous, carbonaceous, nodular pyrite, with thin laminae of SILTSTONE, light grey quartz.
4'10"	SILTSTONE, light grey, quartz, micaceous, with irregular laminae, SHALE, medium grey, micaceous, carbonaceous sideritic becoming more shaly towards base.
2'8"	SANDSTONE, light to dark brown due to oil staining, fine to coarse grained, quartz, subangular to subrounded, well sorted, good porosity.
1'4"	SHALE, medium dark grey to dark grey, micromicaceous, carbonaceous flecks, with scattered laminae of SILTSTONE, light grey, quartz, hard, sideritic, few scattered plant fragments.
9'1"	SHALE, medium dark grey to dark grey, micaceous, hard, sideritic, few scattered plant fragments, minor vertical fractures, finely pyritic towards base.
4'9"	SILTSTONE, light grey to medium light grey, micaceous, calcareous, sideritic, carbonaceous flecks, pyritic.
0'7"	SHALE, medium dark grey to dark grey, micromicaceous, calcareous, fossiliferous (ostracods).
7'1"	SHALE to SILTSTONE, as at 4'9" above.
1'7"	SHALE, medium dark grey, micaceous, calcareous, sideritic, finely carbonaceous, minor slickensides.
0'6"	SILTSTONE, as at 4'9" above with irregular shaly laminae and pyrite veins.
3'8"	SHALE, light grey to medium light grey, soft, bentonitic, argillaceous, few bituminous streaks, minor slickensides.
0'10"	SHALE, as above, very fossiliferous (pelecypods, gastropods, ostracods).
0'6"	SHALE, as immediately above, calcareous, few plant fragments.

Core 3	4619-4679 Recovery 59'7"
1'10"	SHALE, as in basal 0'6" of Core 2.
3'4"	SILTSTONE, medium grey to medium dark grey, micaceous, argillaceous, carbonaceous, sideritic. Distinct contact with overlying unit.
2'4"	SHALE, medium dark grey to dark grey, micaceous, blocky, with fine silty laminae, in part brecciated, minor slickensides.
6'0"	SILTSTONE, very light grey to light grey, micaceous, sideritic, slightly calcareous, carbonaceous in part, with irregularly shaly laminae, pyrite common.
6'10"	SILTSTONE, light olive grey to light grey, micaceous, calcareous, sideritic, very fossiliferous (pelecypods, gastropods, ostracods), irregular mottling, disseminated pyrite.
0'5"	SHALE, medium grey to medium dark grey, soft, calcareous, bentonitic, argillaceous, fossiliferous (pelecypods, gastropods, ostracods), few bituminous impregnations and coalified plant fragments.
0'5"	SHALE, light grey to medium light grey, argillaceous, bituminous impregnations.
4'10"	SILTSTONE, light grey to medium light grey, calcareous, sideritic, carbonaceous in part, very fossiliferous, pyritic.
5'4"	SILTSTONE, light olive grey to light grey, micaceous, calcareous, sideritic, very fossiliferous (pelecypods, gastropods, ostracods), irregular mottling, disseminated pyrite, with irregular shaly laminae.
0'4"	SHALE, dark grey to greyish black, slightly calcareous, micaceous, carbonaceous, blocky, pyritic (disseminated and in nodules), pyritized fossils.
0'8"	SILTSTONE, light grey, quartz, argillaceous carbonaceous.
4'5"	SANDSTONE, light olive grey, fine to coarse grained, quartz, subangular to subrounded, well sorted, slightly silty, sideritic, friable, irregularly mottled and interlaminated

	with shale. Fair to good porosity. Interval spottily-saturated and stained with heavy oil. Distinct contact with underlying unit.
0'11"	SHALE, medium dark grey to dark grey, micromicaceous, sideritic, bentonitic, scattered carbonaceous material, abundant nodular pyrite, minor slickensides.
4'2"	SHALE, medium grey to dark grey, micaceous, calcareous, argillaceous, sideritic very fossiliferous (pelecypods, gastropods, ostracods).
0'8"	SHALE, dark grey to black, calcareous, argillaceous, sideritic, pyritic, very fossiliferous.
1'10"	SHALE, dark grey to black, non-calcareous, carbonaceous, sideritic, fossiliferous, minor slickensides.
2'3"	SHALE, medium dark grey to dark grey, non-calcareous, micromicaceous, carbonaceous, with few thin irregular lentils of SILTSTONE, light grey, sideritic.
3'9"	SANDSTONE, light grey to medium light olive grey, very fine to fine grained, quartz, subangular to subrounded, well sorted, micaceous and carbonaceous in part, with scattered irregular laminae of SILTSTONE, light olive grey, slightly sideritic, pyrite common. Fair to poor porosity.
2'3"	SHALE to SILTSTONE, dark grey to black, slightly carbonaceous, sideritic, abundant pyritized fossils, few bituminous streaks.
3'10"	SHALE, greyish black, micaceous, sideritic, carbonaceous, fossiliferous, few bituminous streaks, pyritic. Well developed slickensides (zone 1' thick) 1'3" from base of unit.
3'2"	SILTSTONE, light grey, quartz, sideritic, pyritic, with minor irregular lentils of SANDSTONE, very light grey, very fine grained, quartz.
Core 4	4679-4719 Recovery 39'11"
2'0"	As in basal 3'2" of Core 3 with pyrite nodules common, coaly band ($1\frac{1}{2}$") at base.

4'0"	SHALE, dark grey to greyish black, micromicaceous, very finely carbonaceous, with irregular mottlings, laminae and thin interbeds of SILTSTONE, light grey, quartz, sideritic, with few plant fragments and bituminous streaks.
2'4"	SILTSTONE, light olive grey to light grey, micaceous, sideritic, minor carbonaceous material.
0'8"	SHALE, dark grey to greyish black, micaceous, carbonaceous, few bituminous streaks. Nodular and disseminated pyrite common.
1'0"	SILTSTONE as at 2'4" above.
1'0"	SHALE as at 0'8" above.
0'9"	SILTSTONE as at 2'4" above with few bituminous streaks.
0'11"	SHALE as at 4'0" above.
5'1"	SHALE, dark grey to greyish black, hard, micaceous, sideritic, with bituminous streaks.
2'11"	SILTSTONE, very light grey to light grey, quartz, sideritic, pyritic, with minor carbonaceous material.
1'0"	SHALE as at 5'1" above.
0'6"	SILTSTONE as at 2'11" above, to SANDSTONE, light grey, very fine grained, quartz, irregularly laminated with SHALE, dark grey with few coalified plant fragments.
3'7"	SHALE, dark grey to greyish black, hard, micaceous, sideritic, coalified and pyritized plant fragments, minor bituminous streaks, pyrite nodules common.
0'8"	SILTSTONE, light grey to medium light grey, quartz, argillaceous, carbonaceous, sideritic, pyrite common. Distinct contact with overlying unit.
2'3"	SHALE as at 3'7" above, blocky, minor slickensides at base.
3'5"	SILTSTONE as at above to SANDSTONE, very light grey to light grey, very fine grained, argillaceous, sideritic, pyritic.
2'4"	SHALE, medium grey, micromicaceous, carbonaceous.

Slickensides common, distinct basal contact.

4'10"	SANDSTONE, light olive grey, very fine grained, quartz, subangular to subrounded, fair to poor sorting, silty, sideritic, pyritic, minor carbonaceous and bituminous material, becomes fine grained towards base. Poor porosity.
0'8"	SANDSTONE, medium light grey to medium grey, very fine to medium grained, quartz, subangular to subrounded, poorly sorted, indurated, slightly micaceous, pyritic, few chert pebbles.

HB Pan Am Wintering Hills 11-33

Lsd. 11, Sec. 33, Twp. 25, Rge. 20, W4M

Elevation 3132.1' K.B.

Core 1 4720-4770 Recovery 50'

There is a depth discrepancy of eleven feet between the driller's total depth (4910') and Schlumberger's (T.D. 4899).

0'5"	SILTSTONE to SANDSTONE, greenish grey, very fine grained, "salt and pepper", subangular to subrounded, fair to poor sorting, micaceous and carbonaceous along bedding planes, sideritic, with thin irregular laminae of SHALE, dark grey, micaceous, carbonaceous, pyrite common.
4'7"	SHALE, dark grey, waxy, soft, micromicaceous, minor carbonaceous material, grading into SILTSTONE, medium grey to medium dark grey, micromicaceous, bituminous impregnations, carbonaceous, pyritic, in basal 1'.
1'10"	SANDSTONE, light olive grey, very fine to fine grained, "salt and pepper", subangular to subrounded, fair to poor sorting, micaceous and carbonaceous along bedding planes, sideritic, pyritic. Poor porosity.
2'2"	SANDSTONE to SILTSTONE, greenish grey, "salt and pepper", micaceous and carbonaceous along bedding planes.
5'0"	SILTSTONE, medium grey to medium dark grey, micro-micaceous, carbonaceous, pyritic, with irregular very thin interbeds of SANDSTONE, greenish grey to light olive grey, very fine grained, "salt and pepper", subangular to subrounded, fair to poor sorting, silty, sideritic in part.
1'9"	SANDSTONE as at 1'10" above, with minor plant remains.
0'7"	SHALE as at 4'7" above.
0'10"	SILTSTONE to SHALE, greenish grey, micromicaceous, sideritic, carbonaceous, pyritic, carbonized plant fragments common.
6'7"	SANDSTONE as at 1'10" above, with thin irregular shaly

	laminae towards base.
2'0"	SILTSTONE to SHALE as at 0'10" above, irregularly interbedded and laminated with SHALE, medium dark grey to dark grey, micromicaceous, silty, carbonaceous, abundant mottling, nodular pyrite.
1.0"	SANDSTONE to SILTSTONE, as at 2'2" above.
3'3"	SANDSTONE, very fine grained to SILTSTONE, medium dark grey, "salt and pepper", scattered carbonaceous material and wood fragments, nodular and disseminated pyrite common.
4'0"	SANDSTONE, as at 1'10" above.
9'6"	SANDSTONE, light olive grey, fine to medium grained, "salt and pepper", subrounded, fair sorting, slightly micaceous and carbonaceous along bedding planes, sideritic, pyritic. Fair to poor porosity.
0'6"	SANDSTONE, as above with abundant siderite and carbonaceous material, pyrite common.
2'0"	SANDSTONE, as at 9'6" above.
3'8"	SHALE, medium dark grey, micromicaceous, flecked with carbonaceous material, with scattered laminae of SILTSTONE, light grey "salt and pepper", carbonaceous, showing horizontal and cross bedding.
0'4"	SHALE, medium grey to medium dark grey, hackly fracture, micromicaceous with irregular silty laminae, disseminated pyrite.
Core 2	4770-4820 Recovery 40'
4'0"	SHALE, as at base of Core 1, sideritic in part.
1'9"	SHALE, medium grey to medium dark grey, hackly fracture, calcareous, micromicaceous, flecked with carbonaceous material, with minor thin irregular silty laminae.
0'3"	LIMESTONE, light olive grey, very finely crystalline to microcrystalline, dense, very small calcite filled vugs and irregular calcite veins, scattered small pyrite nodules.

2'6"	SHALE, medium grey to medium dark grey, hackly fracture, non-calcareous, slightly silty, micromicaceous, flecked with carbonaceous material, abundant nodular pyrite.
1'6"	LIMESTONE, as at 0'3" above.
5'6"	LIMESTONE, medium light grey buff, very finely crystalline to microcrystalline, dense, with irregular pyritic veins and common pyrite nodules.
3'10"	SHALE, medium dark grey to dark grey, slightly silty, micromicaceous, slightly calcareous, carbonaceous, fossiliferous in part, minor bituminous impregnations.
1'1"	SHALE, medium dark grey to dark grey, soft, silty, micro-micaceous, carbonaceous, pyrite nodules common, especially at basal contact. Top 3" and basal 5" are consolidated, intervening section is rubbly.
5'8"	SILTSTONE to SANDSTONE, light olive grey, very fine to fine grained, quartz, subangular to subrounded, fair sorting, silty, rare pyrite nodules, with minor irregular shaly laminae.
1.2"	SHALE, light grey, calcareous, very fossiliferous (pelecypods gastropods, ostracods), minor nodular and disseminated pyrite.
3'0"	SILTSTONE to SANDSTONE, as at 5'8" above.
0'11"	SANDSTONE to SILTSTONE, olive grey, very fossiliferous (pelecypods, gastropods, ostracods), silty, micaceous, worm borings common. Minor disseminated pyrite.
3'0"	SANDSTONE to SILTSTONE, light olive grey, silty, micaceous with abundant disseminated pyrite, minor pyrite nodules.
2'8"	As immediately above, very fossiliferous (pelecypods, gastropods, ostracods), with minor scattered carbonaceous material, becomes very pyritic towards base.
3'2"	SHALE, dark grey to greyish black, soft, rubbly micro-micaceous, with thin coaly laminae, minor disseminated and nodular pyrite.

Core 3	4820-4850 Recovery 20'
0'4"	SHALE, medium grey to dark grey, micromicaceous, calcareous, fossiliferous (pelecypods, gastropods, ostracods), very pyritic (disseminated and in nodules), mottled, with irregular silty laminae.
3'0"	SILTSTONE, light olive grey to olive grey, quartz, micaceous, carbonaceous, sideritic, with abundant irregular mottling, lamination, and thin bedding of SHALE, medium grey to dark grey, silty, micaceous, carbonaceous.
5'6"	SHALE, dark grey to greyish black, slightly silty, micromicaceous, calcareous, fossiliferous (pelecypods, gastropods, ostracods), with highly irregular silty laminae, pyritic.
1'0"	SHALE, dark grey, soft, micromicaceous with bituminous streaks and minor slickensides.
10'2"	SANDSTONE, yellowish grey, very fine to fine grained, occasionally medium grained, quartz, subangular to subrounded, fair sorting, sideritic, iron stained in part, abundant pyrite nodules, angular chert fragments (up to 3/4" dia.) common towards base. Poor porosity.

Leduc Consolidated Socony Chancellor No. 3

Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M

Elevation 2996' K.B.

Core 1 — 4621-4623 Recovery 0'11"

0'11" — SANDSTONE, light olive grey to light grey, very fine grained, "salt and pepper", angular to subangular, poorly sorted, silty, slightly micaceous, thin bedded, pyrite common. Poor porosity.

Core 2 — 4623-4625 Recovery 1'9"

1'9" — SILTSTONE, light grey to medium light grey, "salt and pepper", with carbonaceous flecks. Scattered thin laminae of SHALE, medium dark grey, micaceous, with carbonaceous flecks and occasional coaly streaks.

Core 3 — 4625-4630 Recovery 3'6"

3'6" — SILTSTONE, as above, becoming shaly in basal 2'.

Core 4 — 4630-4635 Recovery 5'8"

5'8" — SILTSTONE, as above. Basal 1' consists of SILTSTONE to SANDSTONE, medium light grey to medium grey, "salt and pepper", silty, micaceous, calcareous carbonaceous in part, pyrite common.

Core 5 — 4635-4640 Recovery 4'10"

4'10" — SILTSTONE, light grey to medium light grey, "salt and pepper", carbonaceous, abundant fine irregular laminae of SHALE, medium dark grey, silty, micaceous, carbonaceous. Pyrite common.

Core 6 — 4640-4645 No recovery.

Core 7	4645-4646 Recovery 0'4"
0'4"	SHALE, medium dark grey, silty, micromicaceous, carbonaceous, slightly calcareous pyritic, with laminae of SILTSTONE, light grey to medium light grey, "salt and pepper", carbonaceous, showing cross bedding.
Core 8	4646-4648 Recovery 0'5"
0'5"	SHALE and SILTSTONE as in Cores 5 and 7 above.
Core 9	4648-4650 Recovery 1'8"
1'2"	SILTSTONE, light olive grey, micaceous slightly calcareous, with carbonaceous flecks, hard, sideritic. Pyrite common.
0'6"	SILTSTONE to SANDSTONE, medium grey to medium light grey, very fine grained, "salt and pepper", micaceous, slightly calcareous, pyritic.
Core 10	4650-4655 Recovery 5'7"
0'5"	SILTSTONE, light grey to medium light grey, "salt and pepper", carbonaceous flecks, irregularly laminated with SHALE, medium grey, silty in part, micaceous, occasional coaly streaks.
0'8"	As in basal 6" of Core 9.
0'10"	SILTSTONE, light grey to medium light grey, "salt and pepper", micaceous, with carbonaceous flecks, pyritic, with irregular interbeds and laminae of SHALE, medium dark grey, silty, micaceous, carbonaceous, pyrite common.
0'11"	SILTSTONE to SANDSTONE, as in basal 6" of Core 9.
2'9"	SILTSTONE, light grey to medium light grey, "salt and pepper", micaceous with carbonaceous flecks, pyritic, with irregular interbeds and laminae of SHALE, medium dark grey, silty, micaceous, carbonaceous. Pyrite common.
Core 11	4655-4660 Recovery 2'11"
0'8"	SILTSTONE and SHALE as in basal 2'9" of Core 10.

2'3"	SANDSTONE, light olive grey, very fine to medium grained, quartz, "salt and pepper", subangular to subrounded, fairly well sorted, silty, micaceous, slightly calcareous, friable, pyritic. Fair to good porosity.
Core 12	4660-4665 Recovery 2'11"
1'0"	SHALE, light grey to medium light grey, silty in part, micaceous, carbonaceous, calcareous, with irregular laminae and thin beds of SILTSTONE, light grey to medium light grey, "salt and pepper", micaceous, carbonaceous.
0'3"	SHALE, light grey to medium light grey, slightly silty, micaceous, carbonaceous, sideritic in part.
0'5"	SANDSTONE, light grey to medium light grey, very fine grained, quartz "salt and pepper", angular to subangular, poorly sorted, silty, slightly calcareous, carbonaceous. Poor porosity.
1'3"	SILTSTONE, light grey to medium light grey, "salt and pepper", slightly calcareous, carbonaceous flecks, showing horizontal and cross bedding, with laminae of SHALE, medium light grey to medium grey, micromicaceous, slightly silty, carbonaceous.
Core 13	4665-4670 Recovery 5'5"
1'2"	SILTSTONE and SHALE as in basal 1'3" of Core 12.
0'7"	SHALE, medium dark grey, slightly silty, micaceous, carbonaceous, pyritic, thinly interbedded with SILTSTONE, light grey to light olive grey, micaceous, slightly calcareous, with carbonaceous flecks, sideritic, pyritic.
0'2"	SILTSTONE and SHALE as in basal 1'3" of Core 12.
0'6"	SILTSTONE, light grey to light olive grey, micaceous, slightly calcareous with carbonaceous flecks, sideritic, pyritic.
0'3"	SHALE, light grey to medium light grey, slightly silty, micaceous, calcareous, carbonaceous.
0'4"	SILTSTONE and SHALE as in basal 1'3" of Core 12.

1'11"	SANDSTONE, light grey to medium light grey, very fine to fine grained, quartz, "salt and pepper", angular to subangular fairly well sorted, silty, slightly calcareous, slightly carbonaceous. Fair to poor porosity.
0'6"	SILTSTONE and SHALE as in basal 1'3" of Core 12.
Core 14	4670-4675 Recovery 4'4"
1'0"	SANDSTONE, light grey to medium light grey, very fine to fine grained, quartz, "salt and pepper", subangular to subrounded, fairly well sorted, slightly silty, micaceous, slightly calcareous, friable. Fair porosity.
3'4"	SHALE, medium grey to medium dark grey, silty, carbonaceous, banded and thinly interbedded with SILTSTONE, light grey, carbonaceous, pyritic, showing horizontal and cross bedding.
Core 15	4675-4680 Recovery 5'7"
1'8"	SHALE and SILTSTONE as in basal 3'4" of Core 14, sideritic.
3'11"	SHALE, medium grey to medium dark grey, slightly silty, micromicaceous, bentonitic, fissile.
Core 16	4680-4685 Recovery 4'7"
4'0"	SHALE as in basal 3'11" of Core 15.
0'7"	SHALE, light olive grey to medium light grey, slightly silty, carbonaceous, calcareous, pyritic, fissile.
Core 17	4685-4690 Recovery 5'0"
0'5"	SHALE, dark grey to black, silty, in part micromicaceous, very fossiliferous (gastropods, pelecypods, ostracods).
4'7"	SHALE, light grey, slightly silty, micaceous, slightly carbonaceous, pyritic, very fossiliferous (gastropods, pelecypods, ostracods).
Core 18	4690-4695 Recovery 1'6"

1'6"	SHALE as in top 5" of Core 17, pyritic.
Core 19	4695-4704 Recovery 5'6"
5'6"	SHALE as in Core 18, bentonitic, minor slickensiding.
Core 20	4704-4706 Recovery 2'4" + (includes swelling due to bentonite)
2'4"	SHALE, light grey to greenish grey, slightly silty, micaceous, bentonitic, fossiliferous.
Core 21	4706-4708 Recovery 2'0"±
2'0"	SHALE as in Core 20.
Core 22	4708-4710 Recovery 2'8" (includes swelling due to bentonite).
1'2"	SHALE, dark grey, slightly silty, micromicaceous, bentonitic, pyritic, very fossiliferous, (gastropods, pelecypods, ostracods) minor slickensiding.
1'6"	SHALE, as above with scattered irregular laminae of SILTSTONE, light olive grey to light grey, "salt and pepper", micaceous, calcareous, pyritic.
Core 23	Missing.
Core 24	4712-4713 Recovery 0'8"
0'8"	SHALE, medium dark grey to dark grey, slightly silty, micromicaceous, calcareous, carbonaceous, fissile.
Core 25	4713-4726 Recovery 3'10"
0'9"	SHALE as in Core 24.
2'2"	SHALE, medium grey, slightly silty, micaceous, carbonaceous.
0'11"	SILTSTONE to SANDSTONE, light olive grey to light grey,

very fine grained, micaceous, carbonaceous, calcareous in part, fossiliferous (gastropods, pelecypods, ostracods).

Core 26 — 4716-4718 Recovery 2'3"

2'3" — SILTSTONE to SANDSTONE as in basal 0'11" at base of Core 25.

Core 27 — 4718-4720 Recovery 2'0"

2'0" — SANDSTONE to SILTSTONE, light olive grey to light grey, very fine grained, micaceous, carbonaceous, calcareous in part, fossiliferous.

Core 28 — 4720-4725 Recovery 4'10"

4'10" — SILTSTONE, light olive grey to light grey, micaceous, calcareous, pyritic, fossiliferous (gastropods, pelecypods, ostracods). Scattered thin irregular shale partings and laminae near base.

Core 29 — 4725-4730 Recovery 5'0"

2'8" — SHALE, medium dark grey to dark grey, slightly silty, micaceous, carbonaceous, fossiliferous (gastropods, pelecypods, ostracods), with irregular thin interbeds of SILTSTONE, light grey, micaceous.

2'4" — SHALE, light grey to medium light grey, slightly silty, micaceous, carbonaceous, very fossiliferous (gastropods, pelecypods, ostracods). Pyrite nodules common. Minor calcite veining in basal $1\frac{1}{2}$".

Core 30 — 4730-4735 Recovery 4'6"

0'5" — SHALE in basal 2'4" of Core 29.

4'1" — SILTSTONE, light olive grey, micaceous, calcareous, slightly carbonaceous.

Core 31	4735-4740 Recovery 4'5"
1'5"	SILTSTONE, as above.
1'0"	SHALE, dark grey, slightly silty, micaceous, calcareous, slightly carbonaceous, pyritic.
2'0"	SILTSTONE, light grey, micaceous, calcareous, slightly carbonaceous, pyritic.
Core 32	4740-4745 Recovery 0'5" (depth uncertain)
0'5"	SHALE, medium light grey to medium grey, slightly silty, calcareous, bentonitic.
Core 33	4745-4746 Recovery 1'1"
1'1"	SHALE, medium dark grey to dark grey, slightly silty, micaceous, calcareous, carbonaceous, with a few thin irregular silty laminae.
Core 34	4746-4749 Recovery 3'0"
3'0"	SHALE, light grey to medium light grey, silty, micaceous, calcareous in part, slightly carbonaceous, fossiliferous, sideritic, nodular and disseminated pyrite common.
Core 35	4749-4754 Recovery 0'9"
0'9"	SHALE as in Core 34.
Core 36	4754-4755 Recovery 0'8"
0'8"	SHALE, light olive grey, silty, micaceous, slightly carbonaceous.
Core 37	4755-4756 Recovery 1'0"
1'0"	SHALE, light grey, silty, micromicaceous, carbonaceous flecks, with irregular mottlings, pyritic in part.

Core 38	4756-4758 Recovery 0'6"
0'6"	SHALE to SILTSTONE, medium light grey to medium grey, micaceous, calcareous in part, with carbonaceous flecks, and irregular thin laminae of SANDSTONE, light grey, very fine grained, quartz.
Core 39	4758-4760 Recovery 6"
0'6"	SANDSTONE, medium grey to medium dark grey, very fine to medium grained quartz, subangular, poorly sorted, argillaceous, poor porosity.
Core 40	4760-4762 Recovery 1'10"
1'10"	SANDSTONE, yellowish grey, very fine to medium grained, subangular to subrounded, quartz, fairly well sorted, slightly silty, friable at top becoming more consolidated at base. Fair to good porosity.
Core 41	4762-4765 Recovery 1'2"
1'2"	SANDSTONE, as in base of Core 40.
Core 42	4765-4770 Recovery 0'4"
0'4"	SHALE, light grey to medium light grey, micaceous, carbonaceous, pyritic, with few small chert pebbles.
Core 43	4770-4772 Recovery 1'7"
1'7"	SILTSTONE, very light grey, mainly quartz grades into SANDSTONE, as in Core 40.
Core 44	4772-4777 Recovery 4'2"
4'2"	SANDSTONE, light olive grey, fine to medium grained, mainly quartz, subangular to subrounded, fairly well sorted, slightly silty, micaceous, sideritic, minor pyrite, friable, fair to good porosity.

Core 45	4777-4782 Recovery 5'0"
5'0"	SANDSTONE as in Core 44.
Core 46	4782-4785 Recovery 3'4"
3'4"	SANDSTONE as in Core 44.
Core 47	4785-4790 Recovery 1'7"
1'7"	SANDSTONE, as in Core 44, and SILTSTONE, very light grey to yellowish grey, calcareous, sideritic, pyritic.
Core 48	4790-4795 Recovery 4'9"
4'9"	SANDSTONE as in Core 44.
Core 49	4795-4800 Recovery 5'0"
5'0"	SANDSTONE, yellowish grey to light olive grey, fine to medium grained, mainly quartz, subangular to subrounded, fairly well sorted, slightly silty, sideritic, minor pyrite, friable. Fair to good porosity.
Core 50	4805-4810 Recovery 5'10"
5'10"	SANDSTONE, yellowish grey to light olive grey, fine to coarse grained, mainly quartz, subangular to subrounded, fair sorting, slightly silty, sideritic, irregularly laminated with SHALE, light greenish grey waxy, micaceous in basal 1'.
Core 52	4810-4815 Recovery 4'10"
1'4"	SILTSTONE to SANDSTONE, light greenish grey to yellowish grey, very fine grained, mainly quartz, subangular, fair sorting, sideritic.
0'9"	SILTSTONE, greenish grey, mainly quartz, blocky, micaceous, pyritic, irregularly laminated with fine shaly laminae, few scattered chert pebbles, slickensided.

2'9"	SANDSTONE, yellowish grey to light olive grey, fine to coarse grained, mainly quartz, subangular to subrounded, fair sorting, slightly silty, sideritic, abundant angular chert fragments and nodular pyrite in basal 2".
Core 53	4815-4818 Recovery 0'6"
0'6"	Chert fragments only as in base of Core 52.
Core 54	4818-4838 Recovery 19'7"
1'3"	SILTSTONE to SHALE, light greenish grey to greenish grey, waxy, very pyritic (as disseminated grains and in nodules), with scattered angular quartz grains and chert fragments.
8'0"	SILTSTONE, medium light grey to light greenish grey, waxy, micaceous, sideritic, containing abundant angular quartz grains and chert fragments (5" x 2").
4'0"	SILTSTONE to SANDSTONE, yellowish grey to light greenish grey, fine to coarse grained, subangular to subrounded, poorly sorted, poor porosity, irregularly laminated with SHALE, light greenish grey, waxy, very pyritic, micaceous with scattered angular chert fragments.
1'3"	SANDSTONE, yellowish grey to light greenish grey, fine to coarse grained, subangular to subrounded, poorly sorted, poor porosity.
5'1"	SANDSTONE as in Core 50, becoming calcareous towards base. Interval highly sheared, slickensides common.

CPOG SW Hussar No. 11-19

Lsd. 11, Sec. 19, Twp. 26, Rge. 20, W4M

Elevation 3047' K.B.

Core 1	4675-4726 Recovery 51'
1'2"	SANDSTONE, light olive grey, very fine to fine grained, "salt and pepper", subangular to subrounded, fair sorting, slightly silty, slightly micaceous, thin bedded, with minor scattered bituminous streaks. Poor porosity.
5'8"	SHALE, medium dark grey to dark grey, micromicaceous, slightly silty, thinly interbedded with SILTSTONE, light olive grey, showing horizontal and cross bedding, abundant irregular thin coaly partings. Pyrite nodules common.
13'4"	SHALE, medium dark grey to dark grey, micaceous, slightly silty, banded and thinly interbedded with SILTSTONE, light olive grey, showing horizontal and cross bedding, rare scattered wood and coalified fragments. Interbeds become very irregular and contorted towards base. Pyrite nodules common.
8'2"	SANDSTONE, light olive grey, very fine to medium grained, "salt and pepper", subangular, well sorted, slightly silty, micaceous, calcareous, thin bedded. Fair to good porosity.
1'10"	SHALE, medium dark grey to dark grey, micromicaceous, slightly silty, thinly interbedded with SILTSTONE, light olive grey, "salt and pepper", with minor scattered bituminous impregnations. Pyrite nodules common.
3'3"	SILTSTONE, light to medium grey, "salt and pepper", micaceous, pyritic, with carbonaceous flecks, finely cross bedded.
1'5"	SILTSTONE, light to medium grey, "salt and pepper", micaceous, pyritic, with carbonaceous flecks.
3'1"	SHALE and SILTSTONE, as at 13'4" above, with coalified fragments at base.
1'9"	SILTSTONE, light to medium grey, "salt and pepper",

	micaceous, carbonaceous flecks, minor scattered coalified fragments.
2'8"	SILTSTONE, light to medium grey, "salt and pepper", showing cross bedding, micaceous and carbonaceous along bedding planes.
1'8"	SILTSTONE, light to medium grey, "salt and pepper", micaceous and carbonaceous along bedding planes.
1'2"	SILTSTONE to SANDSTONE, light to medium grey, very fine grained, "salt and pepper", micaceous, calcareous, flecked with carbonaceous material.
1'10"	SHALE, medium dark grey to dark grey, slightly silty, scattered plant fragments with SILTSTONE, light olive grey, "salt and pepper", showing horizontal and cross bedding. Pyrite nodules common.
1'0"	SILTSTONE, light grey, "salt and pepper", micaceous, calcareous, carbonaceous flecks.
3'0"	SANDSTONE, very fine grained to SILTSTONE, light to medium grey, "salt and pepper", sideritic, pyritic, micaceous and carbonaceous along bedding planes.

Tenn Ar 1 Hussar No. 14-7

Lsd. 14, Sec. 7, Twp. 26, Rge. 21, W4M

Elevation 2838.9' K.B.

Core 1	4735-4769 Recovery 31'6"
13'7"	SANDSTONE, yellowish grey to light grey, very fine grained to fine grained, occasionally medium grained, quartz, subangular to subrounded, well sorted, slightly micaceous, minor siderite, pyrite nodules common. Fair to good porosity.
14'8"	SANDSTONE, as above, with abundant irregular lamination and interbedding of shale, light grey to light greenish grey, micaceous, silty, carbonaceous pyritic.
3'3"	SHALE, greenish grey to light greenish grey, waxy, very pyritic with abundant scattered angular quartz and chert grains, sideritic in part. Slickensides common. Sharp angular contact with overlying unit.
Core 2	4769-4797 Recovery 26'6"
1'5"	SANDSTONE as at 13'7" in Core 1.
1'6"	SHALE, as at 3'3" in Core 1.
1'1"	SANDSTONE, as at 13'7" in Core 1.
3'6"	SHALE, light greyish green to bluish green, waxy containing abundant angular quartz and chert grains, pyrite very abundant. Interval highly sheared, producing brecciation with matrix having higher sand content, slickensides common.
13'10"	SHALE as above to SILTSTONE, light greyish green, hard, pyritic.
3'2"	SANDSTONE, as at 13'7" in Core 1.
1'4"	LIMESTONE, light brownish grey, coarsely crystalline, abundant pyrite, tight.
0'8"	SHALE, as at 3'6" above.

APPENDIX D

FOSSIL IDENTIFICATIONS

FOSSIL IDENTIFICATIONS

Tenn BD 1 Hussar No. 6-7
Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M
Elevation 3030 feet (K.B.)

Depth (feet)	
4384	Zamites sp.
4408	Athrotaxopis sp.
4412	Ptilophyllum montanense (Fontaine)
4553	Sphaerium sp.
4576	Astarte natosini McLearn

Mobil CPR Parflesh No. 6-20
Lsd. 6, Sec. 20, Twp. 24, Rge. 21, W4M
Elevation 2922 feet (K.B.)

Depth (feet)	
4680	Elliptio sp.
4719	Sphaerium sp.
4728	Pelecypod remains
4735	Unio sp.
4750	Corbula sp., cf. C. palliseri McLearn Sphaerium sp.

CPOG Hussar No. 10-12
Lsd. 10, Sec. 12, Twp. 25, Rge. 20, W4M
Elevation 3024 feet (K.B.)

Depth (feet)	
4633	Pelecypod indeterminate
4641	Corbula sp., cf. C. palliseri McLearn

CPOG Hussar No. 10-12 (Continued)

Depth (feet)	
4649	Corbula fragments
4656	Lioplacodes sp., cf. L. bituminis Russell
4657	Planorbis sp.
4659	Elliptio sp.
4660	Scalez sp.
	Ostracods
4670	Elliptio sp.
4671	Sphaerium sp.

HB Pan Am Wintering Hills No. 11-33
Lsd. 11, Sec. 33, Twp. 25, Rge. 20, W4M
Elevation 3132.1 feet (K.B.)

Depth (feet)	
4734	Conifer needles
4788	Fish fragments
4796	Sphaerium sp.
4797	Tancredia sp.
4801	Astarte? sp.
4806	Tancredia sp.
4807	Tancredia sp.
4820	Scalez sp.

Leduc Consolidated Socony Chancellor No. 3
Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M
Elevation 2996 feet (K.B.)

Depth (feet)	
4708	Pelecypod indeterminate
4718	*Sphaerium* sp.
4722	*Astarte?* sp.
4728	*Scalez* sp.

APPENDIX E

CALIBRATION CURVES FOR X-RAY FLUORESCENCE DETERMINATIONS, CHEMICAL ANALYSES OF STANDARDS, AND TYPICAL FLUORESCENCE OPERATING CONDITIONS

Calibration curves for Mg, Al, Si, K, Ca and Fe expressed in terms of the oxides are shown in Figures 13-I through 13-VI.

Standards R56 and R57 are Cretaceous shales from the Wapiabi Formation. Standards 259533, 259548 and 259563 are selected Pierre shales and standards R66 and R67 are Devono-Mississippian shales from the Besa River Formation.

Table 5 shows typical operating conditions used in X-Ray fluorescence analyses.

Chemically Analysed Shale Standards Employed for Calibration Curves

A. Wapiabi Formation (Upper Cretaceous)

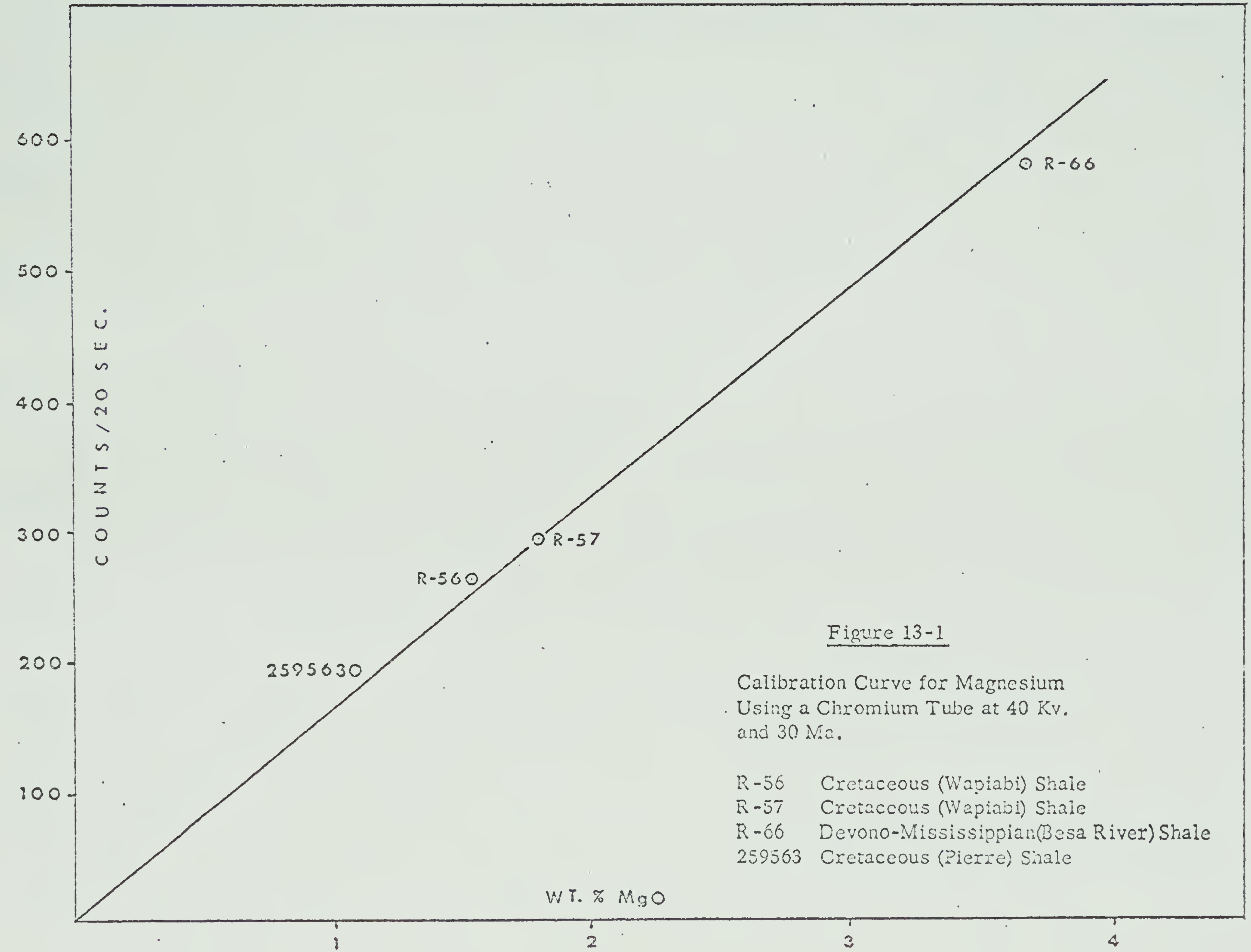
Constituents	R56	R57
SiO_2	74.77%	53.65%
TiO_2	.60	1.08
Al_2O_3	10.27	18.18
Fe_2O_3	3.30	10.23
MnO_2	.02	.03
MgO	1.54	1.81
CaO	1.26	.59
Na_2O	.44	.68
K_2O	2.00	3.76
P_2O_5	.20	.27
H_2O-	.78	1.70
H_2O+	2.96	6.25
CO_2	1.34	Nil
S	.68	1.62
	100.16	99.85
Less FeO as Fe_2O_3	.18	.35
	99.98%	99.50%

B. Pierre Shale (Upper Cretaceous)

Constituents	259533	259548	259563
SiO_2	62.83%	47.12%	64.61%
TiO_2	.33	.24	.71
Al_2O_3	8.36	20.79	14.10
Fe_2O_3	2.06	2.65	.92
FeO	1.93	.56	1.63
MnO_2	4.60	.03	.02
MgO	1.67	3.06	1.08
CaO	3.07	.81	.38
Na_2O	.91	.70	.35
K_2O	1.21	.36	3.37
P_2O_5	.15	.09	.08
H_2O-	2.62	11.62	2.85
H_2O+	3.22	7.30	5.48
CO_2	5.60	.03	.02
S	.60	.26	.27
SO_3	.16	4.01	.37
F	.04	.26	.09
BaO	.00	.00	.03
	99.36	99.89	96.36
Less O	.17	.18	.13
	99.19%	99.71%	96.23%

C. Besa River Formation (Devono-Mississippian)

Constituents	R 66	R 67
SiO_2	58.03%	54.26%
TiO_2	.75	.28
Al_2O_3	17.31	5.55
Fe_2O_3	5.77	1.50
MnO_2	.01	.01
MgO	3.67	1.96
CaO	.84	16.98
Na_2O	.71	.44
K_2O	2.24	.80
P_2O_5	.16	.07
H_2O-	1.55	.41
H_2O+	5.27	1.69
CO_2	Nil	15.32
S	1.30	.60
C	3.88 (?)	.44 (?)
	101.49	100.31
Less FeO as Fe_2O_3	.46	.11
	101.03%	100.20%



<u>Figure 13-1</u>

Calibration Curve for Magnesium Using a Chromium Tube at 40 Kv. and 30 Ma.

R-56	Cretaceous (Wapiabi) Shale
R-57	Cretaceous (Wapiabi) Shale
R-66	Devono-Mississippian(Besa River) Shale
259563	Cretaceous (Pierre) Shale

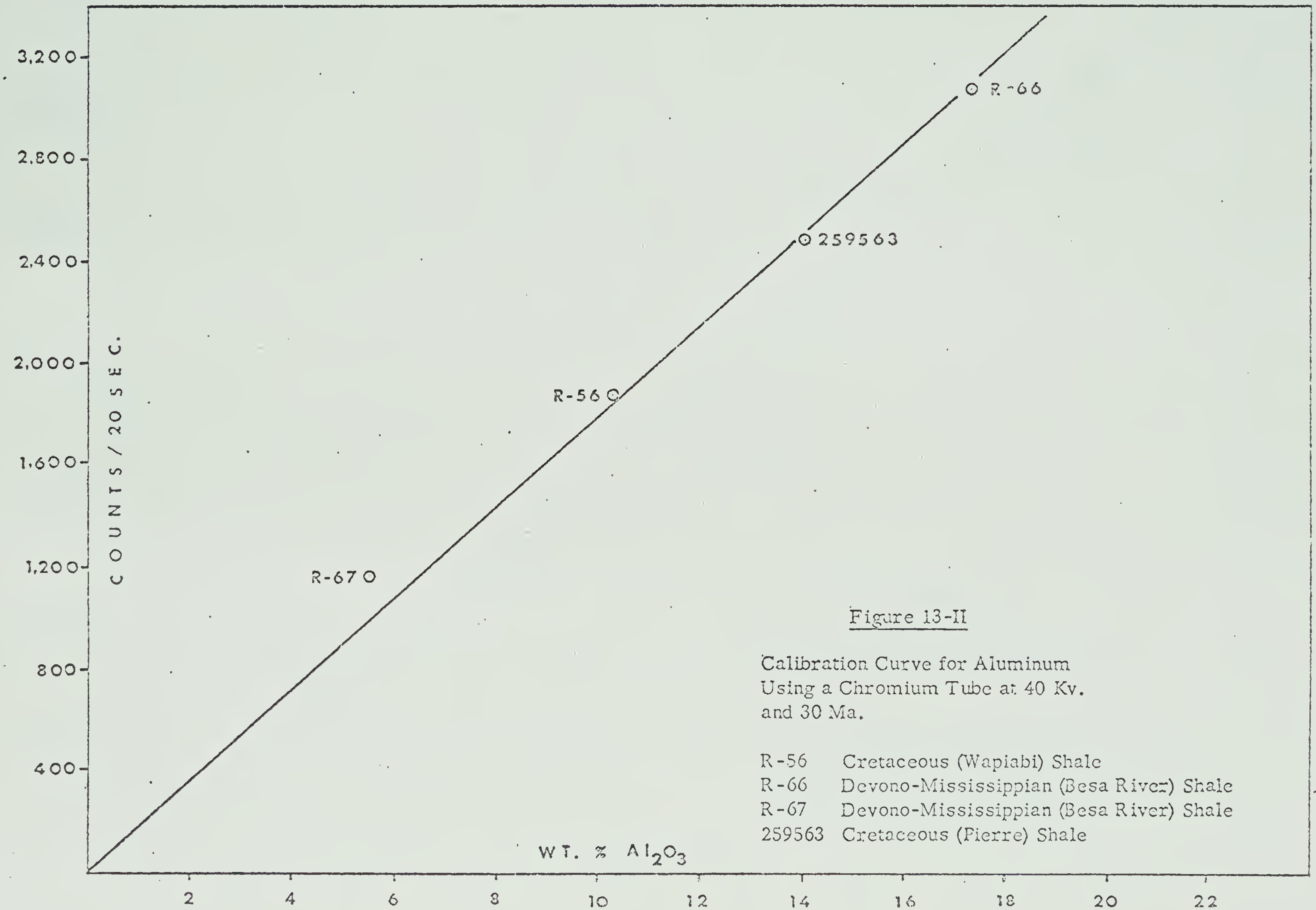


Figure 13-II

Calibration Curve for Aluminum Using a Chromium Tube at 40 Kv. and 30 Ma.

R-56 Cretaceous (Wapiabi) Shale
R-66 Devono-Mississippian (Besa River) Shale
R-67 Devono-Mississippian (Besa River) Shale
259563 Cretaceous (Pierre) Shale

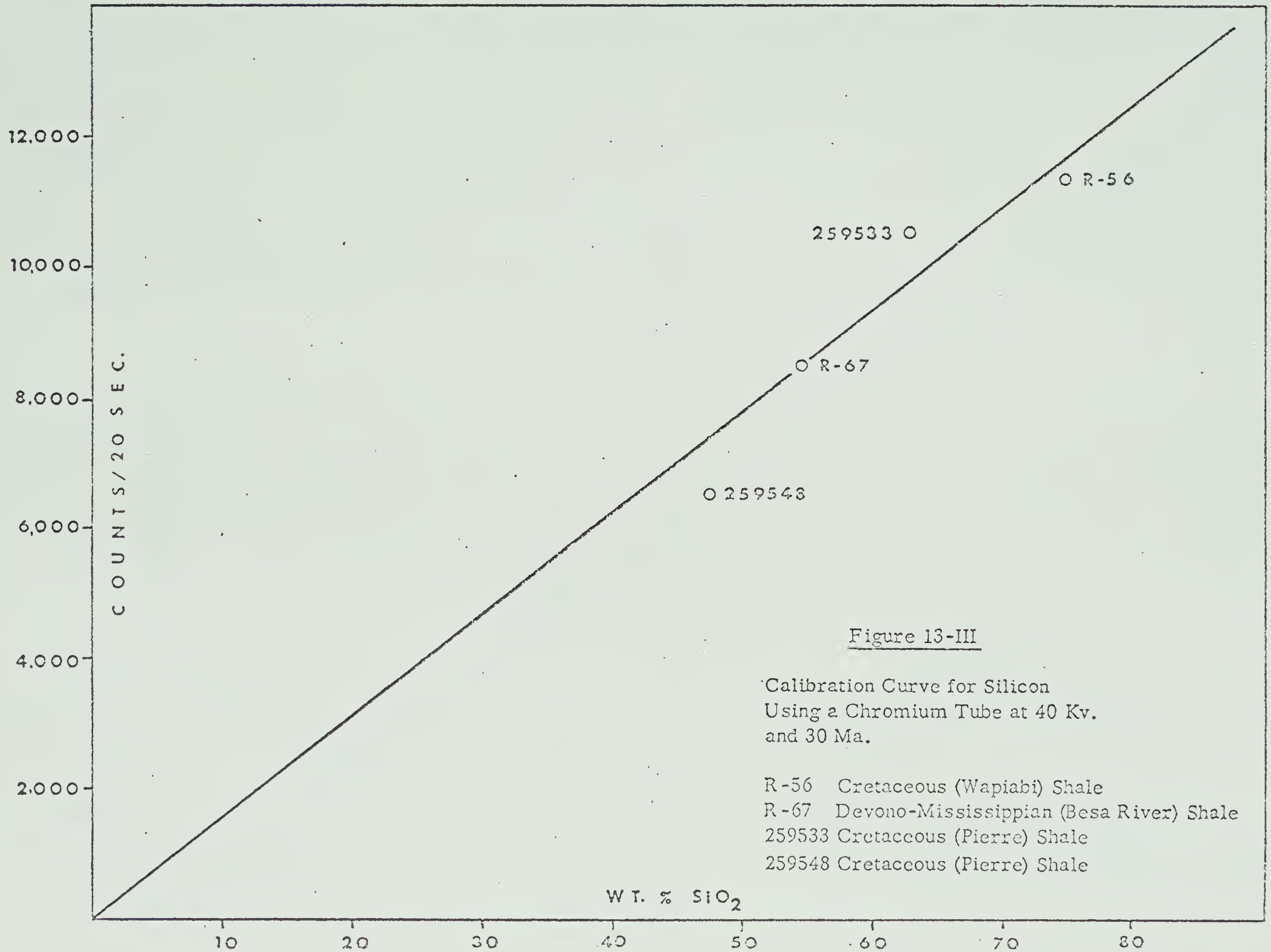


Figure 13-III

Calibration Curve for Silicon
Using a Chromium Tube at 40 Kv.
and 30 Ma.

R-56 Cretaceous (Wapiabi) Shale
R-67 Devono-Mississippian (Besa River) Shale
259533 Cretaceous (Pierre) Shale
259548 Cretaceous (Pierre) Shale

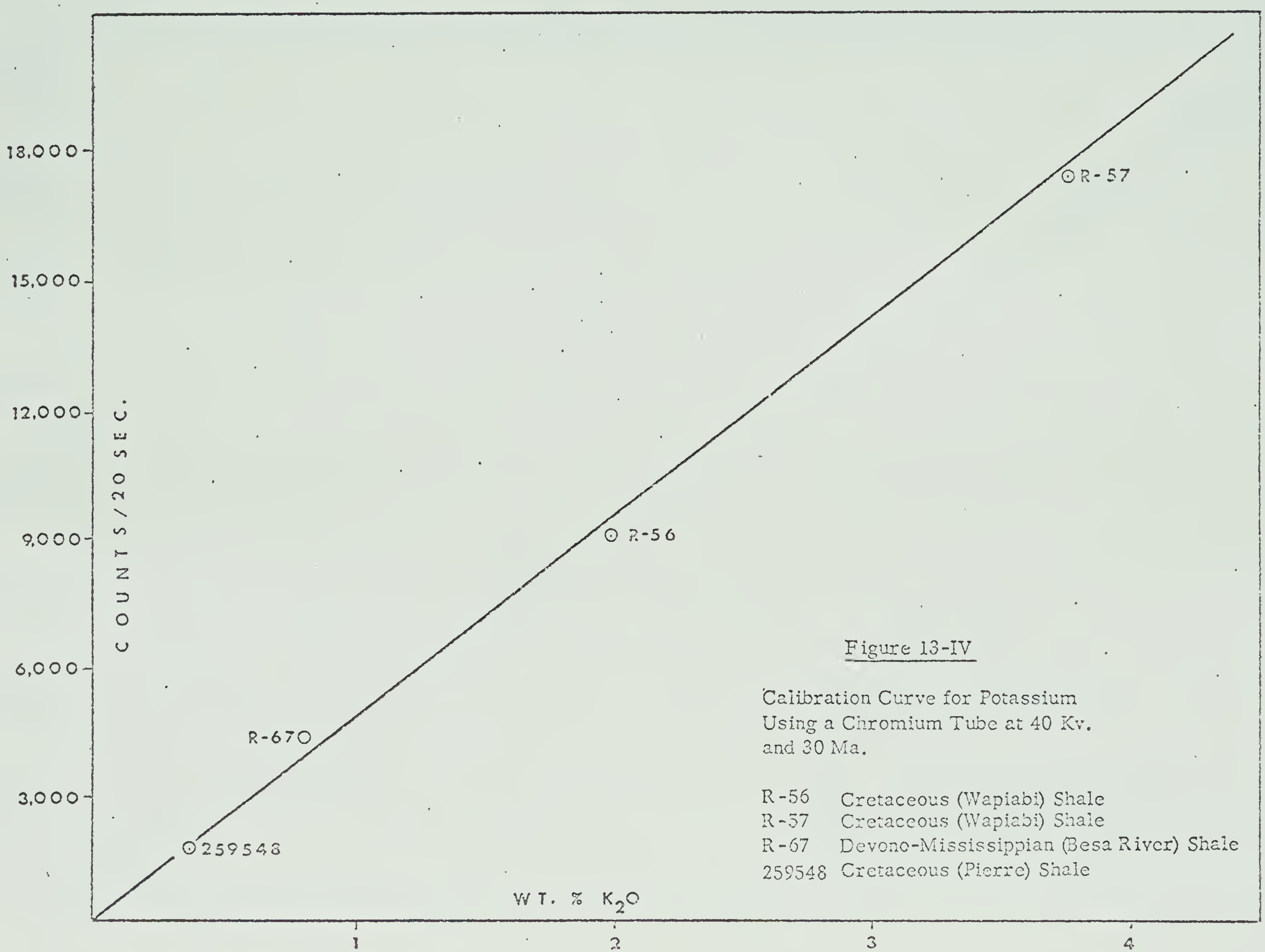


Figure 13-IV

Calibration Curve for Potassium Using a Chromium Tube at 40 Kv. and 30 Ma.

R-56	Cretaceous (Wapiabi) Shale
R-57	Cretaceous (Wapiabi) Shale
R-67	Devono-Mississippian (Besa River) Shale
259548	Cretaceous (Pierre) Shale

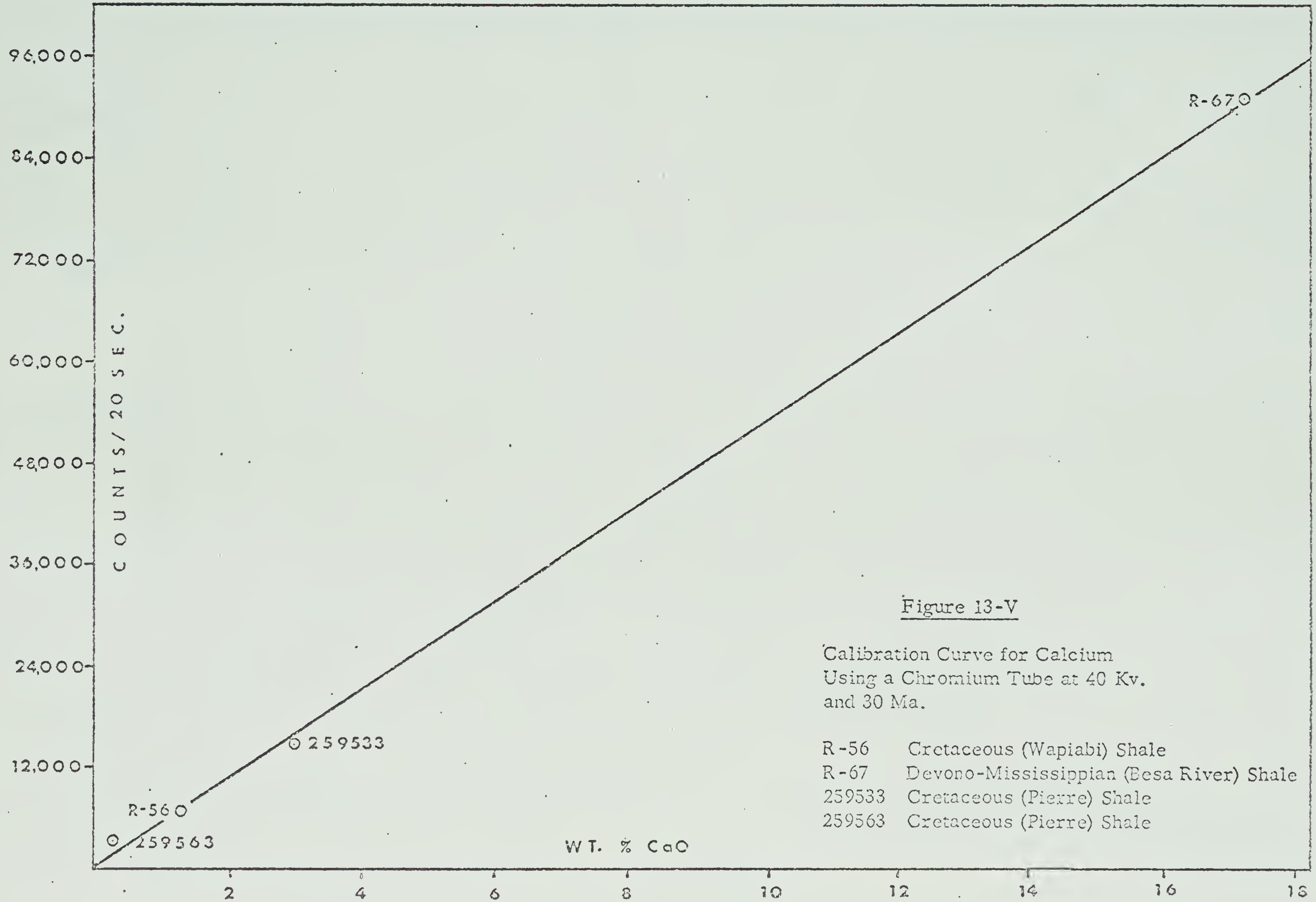


Figure 13-V

Calibration Curve for Calcium
Using a Chromium Tube at 40 Kv.
and 30 Ma.

R-56 Cretaceous (Wapiabi) Shale
R-67 Devono-Mississippian (Besa River) Shale
259533 Cretaceous (Pierre) Shale
259563 Cretaceous (Pierre) Shale

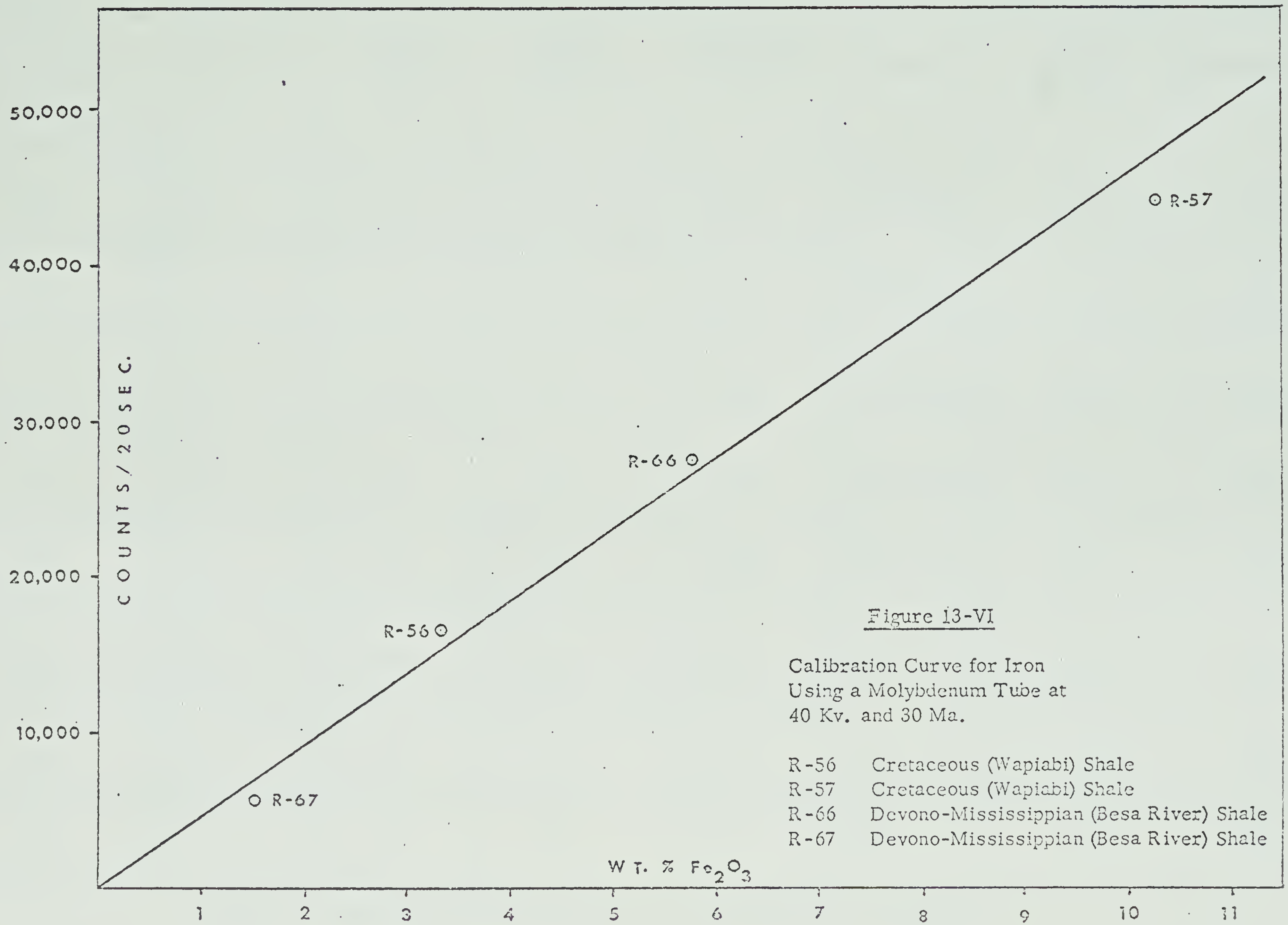


Figure 13-VI

Calibration Curve for Iron
Using a Molybdenum Tube at
40 Kv. and 30 Ma.

R-56 Cretaceous (Wapiabi) Shale
R-57 Cretaceous (Wapiabi) Shale
R-66 Devono-Mississippian (Besa River) Shale
R-67 Devono-Mississippian (Besa River) Shale

ELEMENT	TUBE TYPE	TUBE VOLTAGE Kv.	TUBE AMPERAGE Ma.	ANALYSING CRYSTAL	DETECTOR	PEAK POSITION	BACKGROUND
Mg	Cr	40	30	ADP	Flow proportional	107.65	109.0
Al	Cr.	40	30	EDDT	Flow proportional	113.0	115.50
Si	Cr	40	30	EDDT	Flow proportional	78.30	80.0
K	Cr.	40	30	EDDT	Flow proportional	20.28	19.20
Ca	Cr	40	30	EDDT	Flow proportional	14.76	13.50
Fe	Mo	40	30	LiF	Scint.	57.56	59.50
Sr	Mo	40	30	LiF	Scint.	25.05	24.35 25.75
Rb	Mo	40	30	LiF	Scint.	26.50	26.00 27.00

TABLE 5. OPERATING CONDITIONS FOR X-RAY FLUORESCENCE ANALYSIS

EXPLANATION OF PLATE I

Photographs of Core

Figure 1 — Fort Augustus Formation: Sandstone, light olive grey, fine to medium grained, "salt and pepper", subangular to subrounded, micaceous, sideritic. Joe Phillips Hussar No. 11-1, Lsd. 11, Sec. 1, Twp. 24, Rge. 21, W4M; 4463 feet.

Figure 2 — Fort Augustus Formation: Light colored irregular laminae of siltstone, micaceous and carbonaceous (dark) along bedding planes. Mobil CPR Parflesh No. 6-20, Lsd. 6, Sec. 20, Twp. 24, Rge. 21, W4M; 4636 feet.

Figure 3 — Fort Augustus Formation: Light colored low angle laminations and cross laminations of siltstone interbedded with shale. CPOG Hussar No. 10-12, Lsd. 10, Sec. 12, Twp. 25, Rge. 20, W4M; 4534 feet.

Figure 4 — Fort Augustus Formation: Light colored cross-bedded lenses of siltstone overlying "salt and pepper" sandstone; bituminous streak (arrow). Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4640 feet.

Figure 5 — Fort Augustus Formation: Siltstone and shale, irregularly thinly interlaminated with very thin beds of very fine grained, "salt and pepper" sandstone, micaceous and carbonaceous along bedding planes; disseminated pyrite (arrow). Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4626 feet.

Figure 6 — Fort Augustus Formation: Lenses and stringers of very fine grained "salt and pepper" sandstone irregularly interbedded with carbonaceous shale. Abundant disseminated and nodular pyrite scattered throughout. Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4645 feet.

Figure 7 — *Corbula* sp., cf *C palliseri* McLearn *Sphaerium* sp. (arrow); Mobil CPR Parflesh No. 6-20, Lsd. 6, Sec. 20, Twp. 24, Rge. 21, W4M; 4750 feet. "Calcareous" member of McMurray Formation.

Figure 8 Top left: Astarte? sp.; Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4722 feet. "Calcareous" member of McMurray Formation.

Bottom left: Athrotaxopis sp.; Tenn BD 1 Hussar No. 6-7, Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M; 4408 feet. Fort Augustus Formation.

Right: Tancredia sp.; HB Pan Am Wintering Hills No. 11-33, Lsd. 11, Sec. 33, Twp. 25, Rge. 20, W4M; 4807 feet. "Calcareous" member of McMurray Formation.

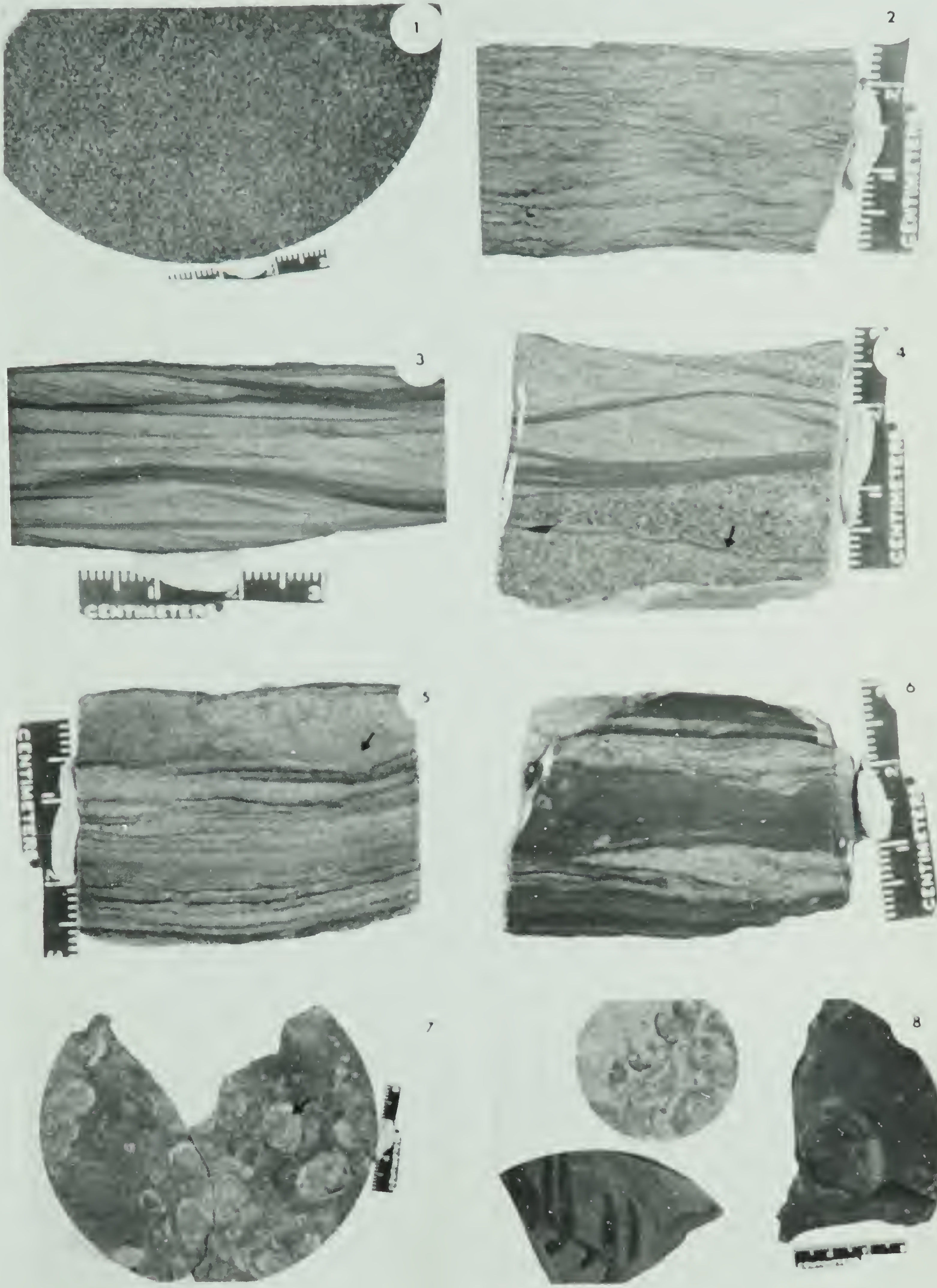


PLATE I.

EXPLANATION OF PLATE II

Photographs of Core

Figure 1 "Calcareous" member of McMurray Formation: Minute neptunian dykes of siltstone in black calcareous shale. Note reticulate pattern. Mobil CPR Parflesh No. 6-20, Lsd. 6, Sec. 20, Twp. 24, Rge. 21, W4M; 4735 feet.

Figure 2 "Calcareous" member of McMurray Formation: Limestone, medium light grey buff, with irregular calcite veining, associated with pyrite. Pyrite nodule at "X", calcite filled vug at "Y". HB Pan Am Wintering Hills No. 11-33, Lsd. 11, Sec. 33, Twp. 25, Rge. 20, W4M; 4783 feet.

Figure 3 Fort Augustus Formation: Light colored lenses of siltstone (arrow) with irregular discontinuous shale partings. Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4655 feet.

Figure 4 "Calcareous" member of McMurray Formation: Light colored siltstone, interbedded with irregular discontinuous shale partings with abundant nodular pyrite. Pyrite nodule at "X". HB Pan Am Wintering Hills No. 11-33, Lsd. 11, Sec. 33, Twp. 25, Rge. 20, W4M; 4824 feet.

Figure 5 Ellerslie-Deville Members of McMurray Formation: Contorted bedding in siltstone and very fine grained sandstone, bituminous streak (arrow). CPOG Hussar No. 10-12, Lsd. 10, Sec. 12, Twp. 25, Rge. 20, W4M; 4701 feet.

Figure 6 Top of Ellerslie-Deville Members of McMurray Formation: Lenses of light colored siltstone associated with carbonate nodules irregularly interbedded with shale, coaly parting (arrow) Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4757 feet.

Figure 7 Ellerslie-Deville Members of McMurray Formation: Breccia of angular chert fragments "X" in matrix of fine grained quartz sandstone. Tenn BD 1 Hussar No. 6-7, Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M; 4657 feet.

Figure 8 Ellerslie-Deville Members of McMurray Formation: Large angular chert fragments (arrow) in matrix of very fine to fine grained sandstone; HB Pan Am Wintering Hills No. 11-33, Lsd. 11, Sec. 33, Twp. 25, Rge. 20, W4M; 4832 feet.

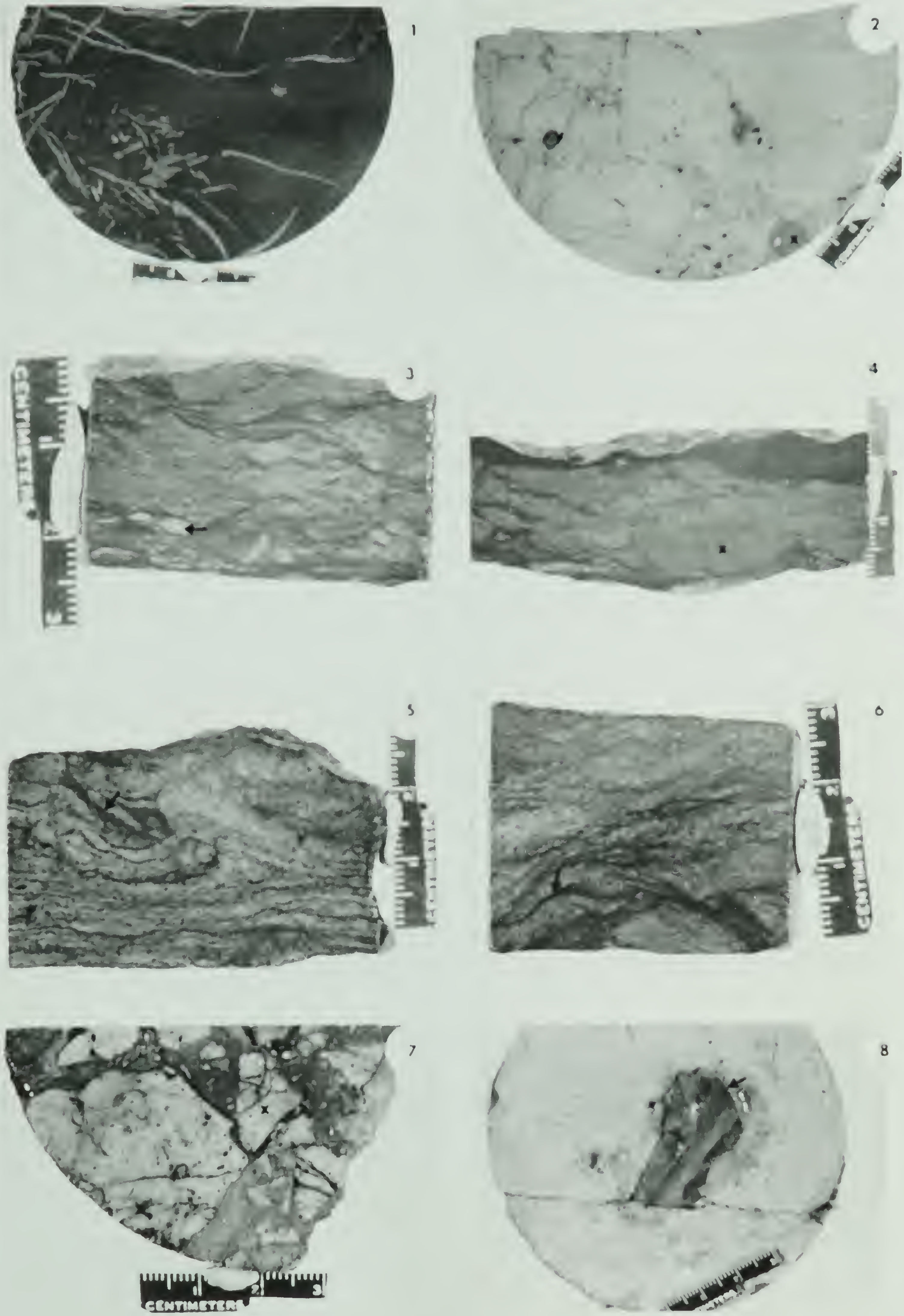


PLATE II.

EXPLANATION OF PLATE III

Photomicrographs of Thin Sections

Figure 1 Ellerslie-Deville Members of McMurray Formation: Authigenic quartz overgrowth on well rounded quartz grain, distinguished by line of impurities. Note criss-cross pattern of globule train inclusions. Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4762 feet. Magnification X16. Nicols crossed.

Figure 2 Ellerslie-Deville Members of McMurray Formation: Polycrystalline quartz grain embedded in matrix and calcite cement. Note straining of individual quartz units in the large polycrystalline quartz. Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4793 feet. Magnification X6·3. Nicols crossed.

Figure 3 Ellerslie-Deville Members of McMurray Formation: Rosette-like aggregate of chalcedony (vein quartz or silicified wood) (centre). Large chert grain (top centre) and polycrystalline quartz (lower left). Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4772 feet. Magnification X16. Nicols crossed.

Figure 4 Fort Augustus Formation: Detrital quartz grain showing fractures and inclusions. Note also globule train inclusions. Tenn BC 1 Hussar No. 6-7, Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M; 4540 feet. Magnification X16. Nicols crossed.

Figure 5 Fort Augustus Formation: Detrital quartz grain replaced and wedged apart by calcite cement. Tenn BD 1 Hussar No. 6-7, Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M; 4595 feet. Magnification X16. Nicols crossed.

Figure 6 Fort Augustus Formation: Chert grain wedged apart by calcite cement (arrow). Quartz being replaced by calcite cement (left of centre). Tenn BD 1 Hussar No. 6-7, Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M; 4595 feet. Magnification X16. Nicols crossed.

Figure 7 Fort Augustus Formation: Detrital plagioclase surrounded and being replaced by calcite cement. Joe Phillips Hussar No. 11-1, Lsd. 11, Sec. 1, Twp. 24, Rge. 21, W4M; 4422 feet. Magnification X40. Nicols crossed.

Figure 8 Fort Augustus Formation: Quartz grains etched and pitted (arrow) and embedded in matrix. Tenn BD 1 Hussar No. 6-7, Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M; 4540 feet. Magnification X16. Nicols crossed.

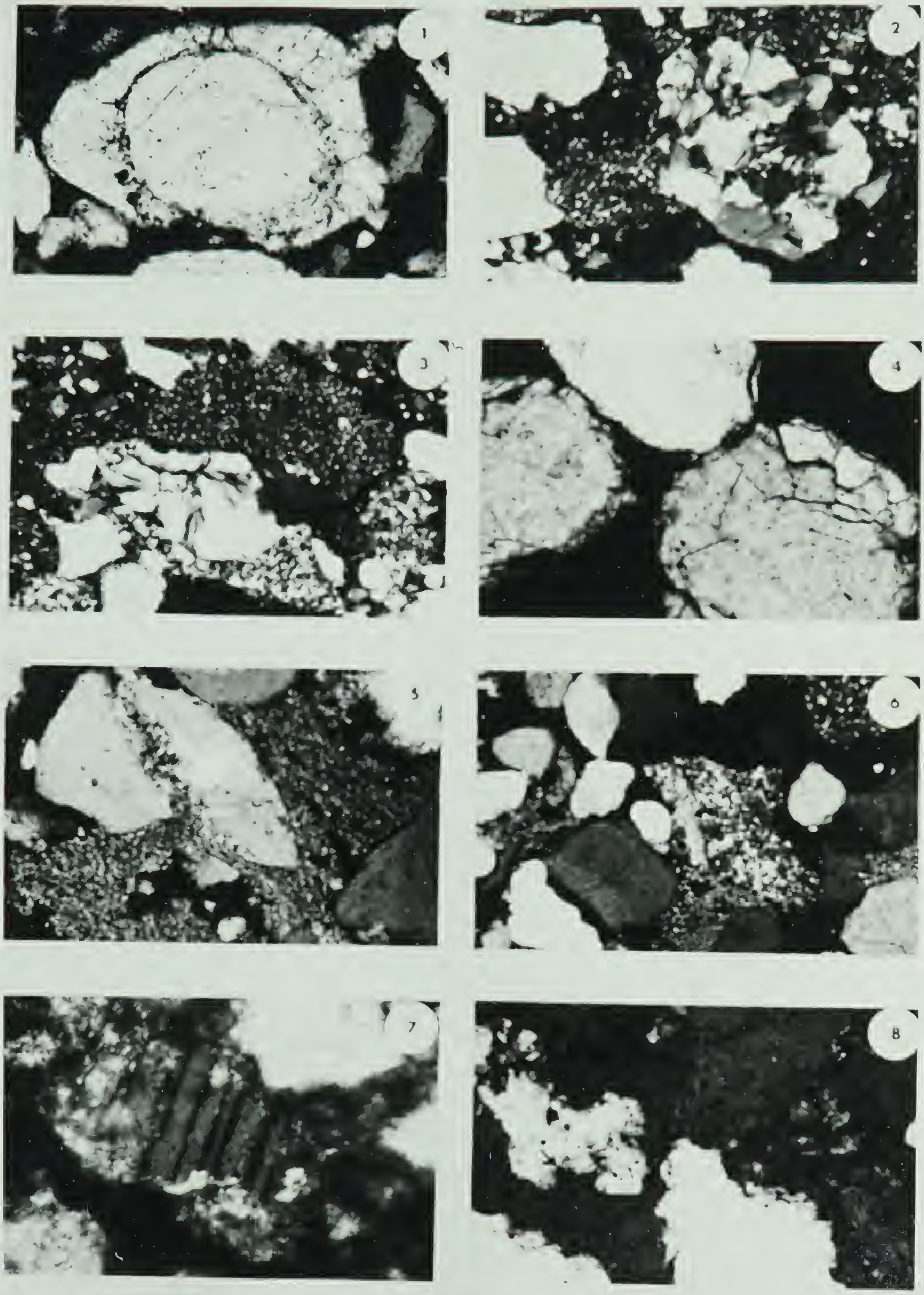


PLATE III.

EXPLANATION OF PLATE IV

Photomicrographs of Thin Sections

Figure 1 Ellerslie-Deville Members of McMurray Formation: Detrital quartz grain showing criss-cross pattern of globule train inclusions. Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4832 feet. Magnification X16. Nicols crossed.

Figure 2 Ellerslie Deville Members of McMurray Formation: Detrital quartz grain with aligned acicular inclusions. Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4810 feet. Magnification X16. Nicols crossed.

Figure 3 Fort Augustus Formation: Quartz grains showing straight contacts. Note acicular and globule inclusions. Tenn BD 1 Hussar No. 6-7, Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M; 4540 feet. Magnification X16. Nicols crossed.

Figure 4 Ellerslie-Deville Members of McMurray Formation: Quartz grains with contacts showing slight interpenetration. Note also aligned stubby acicular inclusions. Leduc Consolidated Socony Chancellor No. 3, Lsd. 2, Sec. 24, Twp. 25, Rge. 21, W4M; 4793 feet. Magnification X16. Nicols not crossed.

Figure 5 Fort Augustus Formation: Recrystallized calcite "rhombs". Note also abundant inclusions in larger quartz grains and replacement of quartz by calcite cement. Tenn BD 1 Hussar No. 6-7, Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M; 4540 feet. Magnification X16. Nicols crossed.

Figure 6 "Calcareous" member of McMurray Formation: Detrital quartz grains, etched and pitted along pore boundaries with authigenic clay material between grains. Tenn BD 1 Hussar No. 6-7, Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M; 4618 feet. Magnification X16. Nicols crossed.

Figure 7 Fort Augustus Formation: Detrital quartz with chlorite and clayey interstitial matrix. Note sub-parallel orientation of elongate grains (arrow). Tenn BD 1 Hussar No. 6-7, Lsd. 6, Sec. 7, Twp. 24, Rge. 19, W4M; 4237 feet. Magnification X16. Nicols crossed.

Figure 8 As in Figure 7, Nicols not crossed.

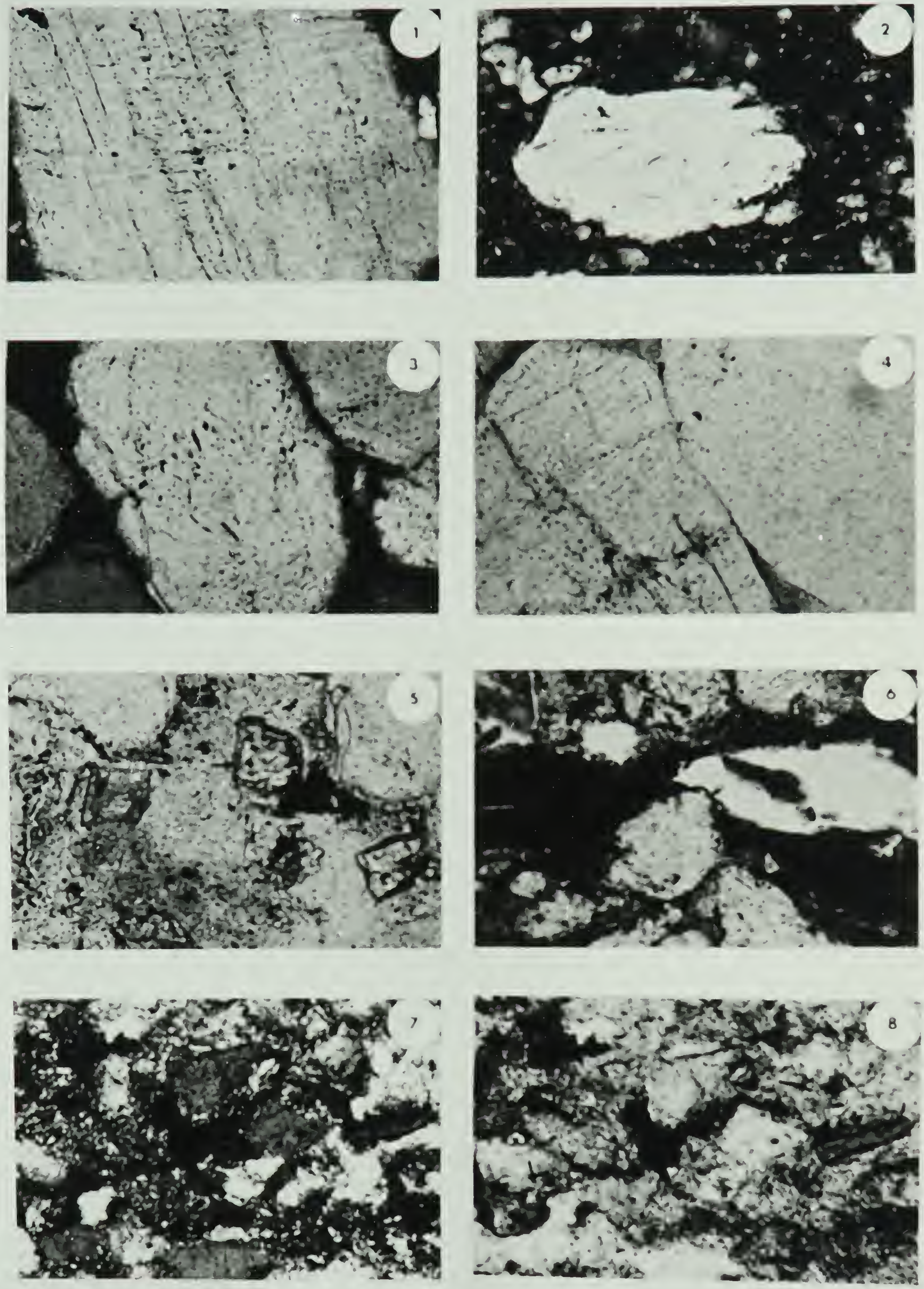
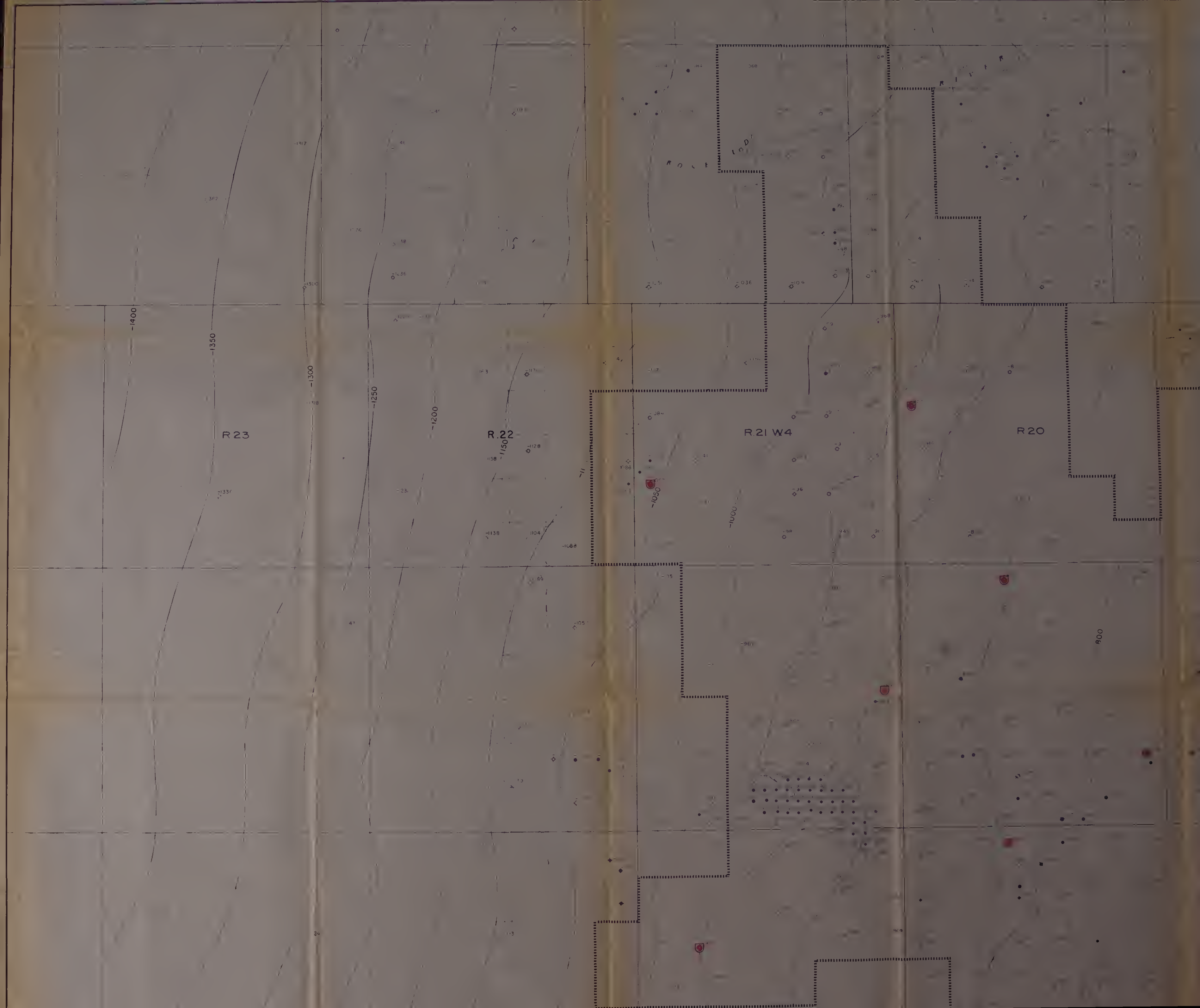
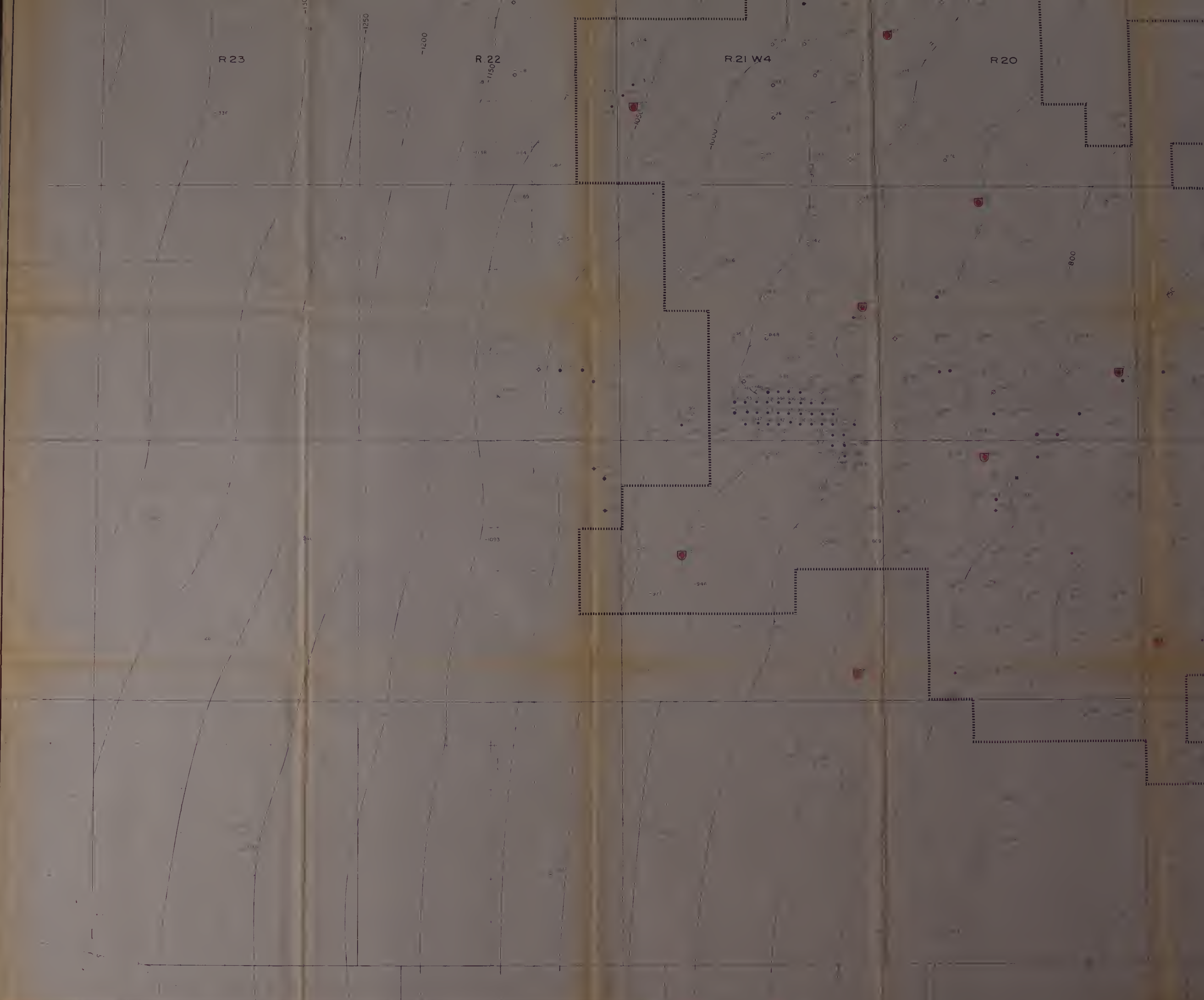


PLATE IV.



R23
R.22
R 21 W4
R20
-1400
-1350
-1300
-1250
-1200
-1150
-1050
-1000
900


R.21 W4
R.20
R.19
T24
T25
T26
T27
-1050
-1000
-950
-900
-850
-800
-750
-700
-650
-600
-550
RED DEER



R 23
R 22
R 21 W4
R 20
-1250
-1200
-1150
-1000
-800
-1093

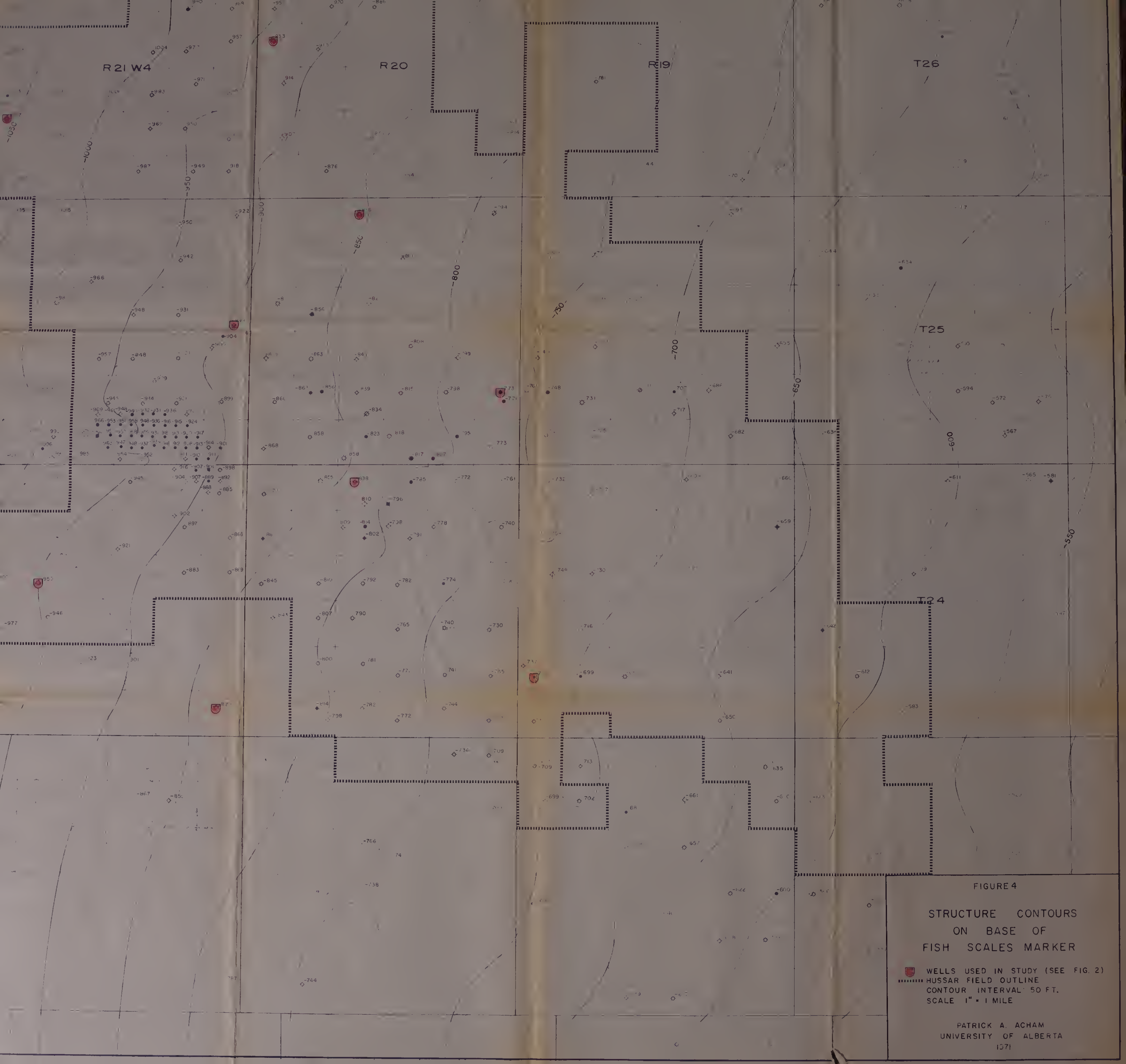
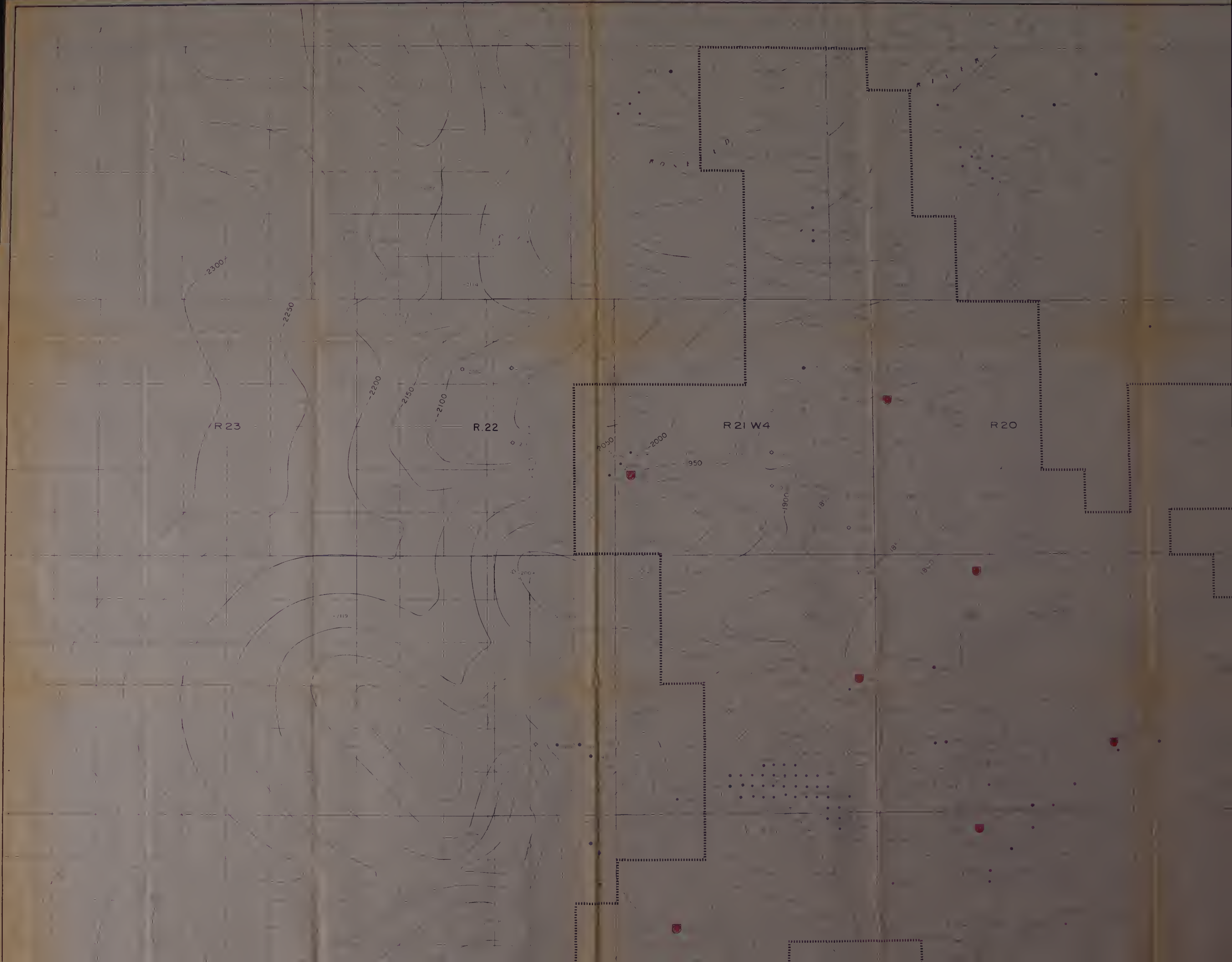
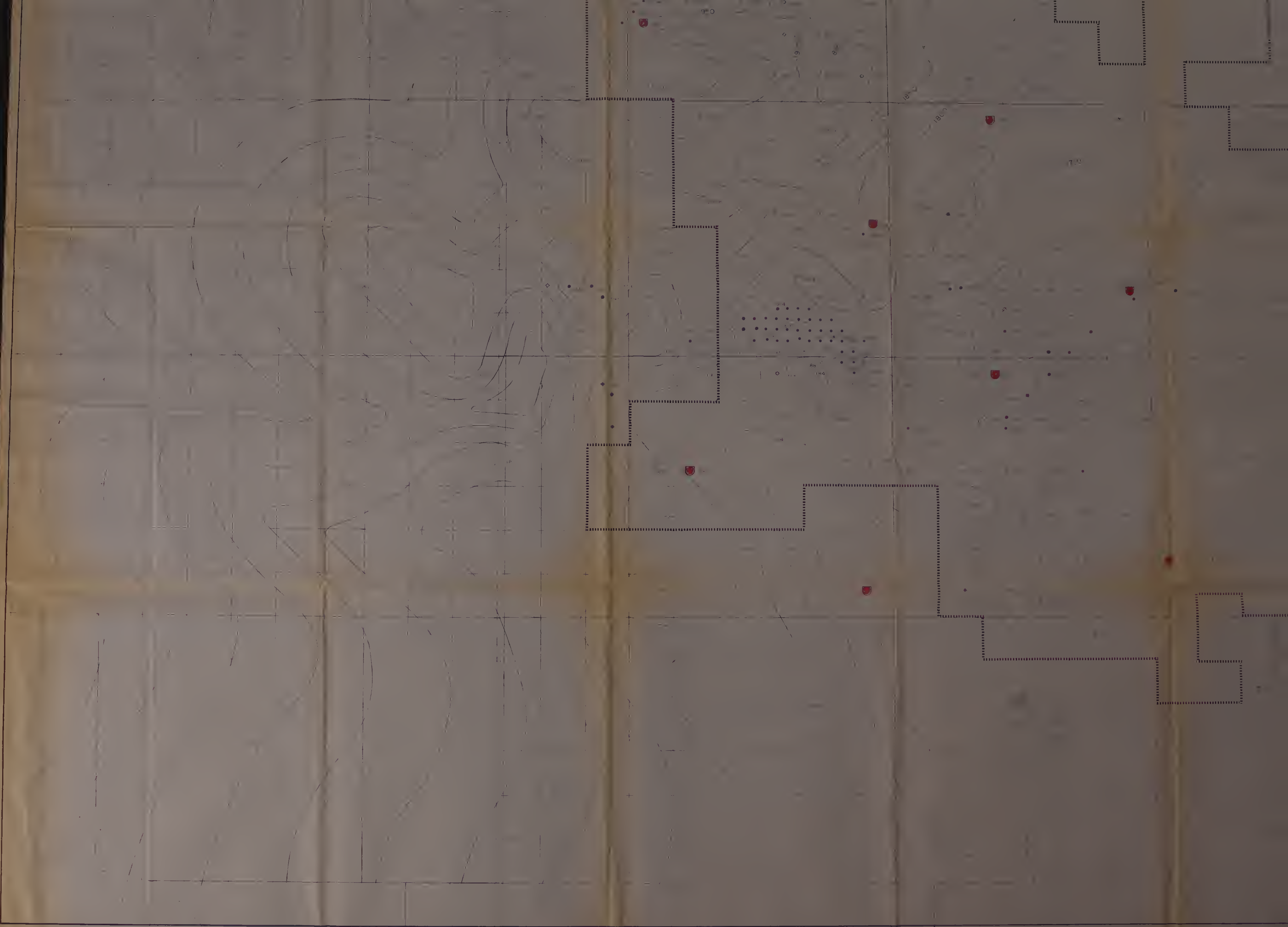


FIGURE 4

STRUCTURE CONTOURS ON BASE OF FISH SCALES MARKER


R23
R.22
R21 W4
R20
2300
2250
2200
2150
2100
2000
1900

R.21 W4
R20
R19
T27
T26
T25
EROSIONAL EDGE OF PEKISKO FORMATION
PEKISKO FM
BANFF
R E D D E E R
-2050
-2000
-1950
-1900
-1850
-1800
-1750



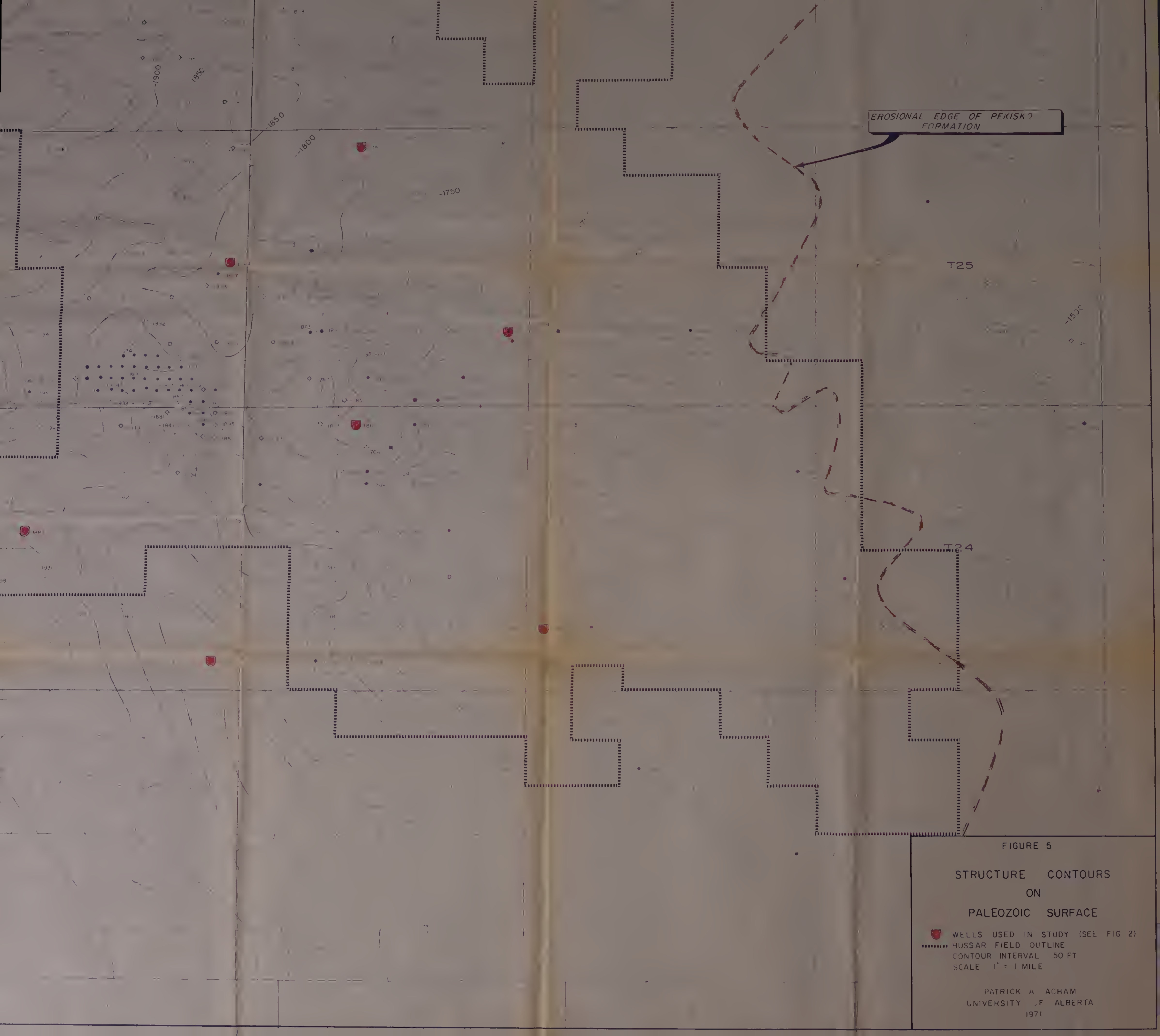
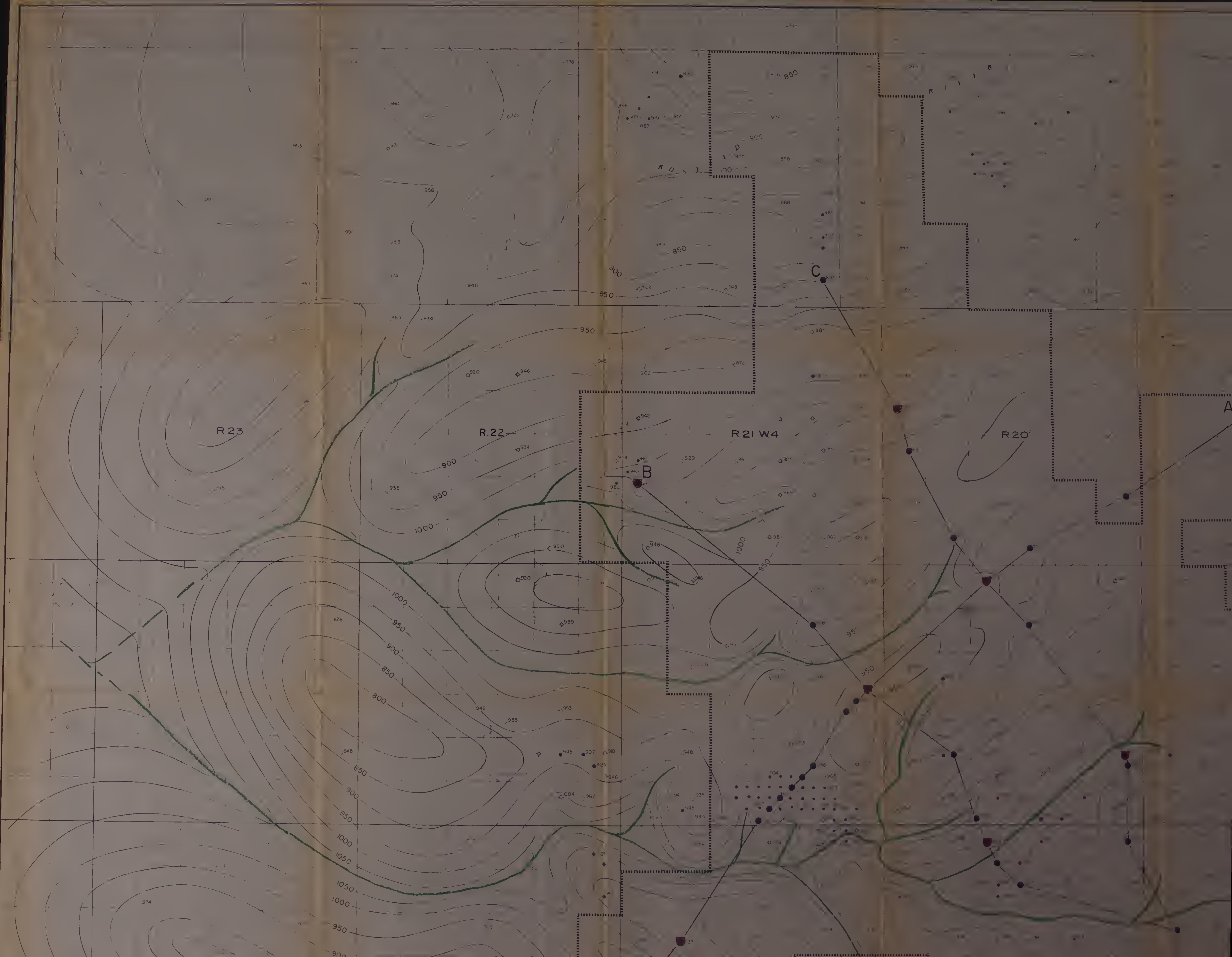


FIGURE 5

STRUCTURE CONTOURS
ON
PALEOZOIC SURFACE

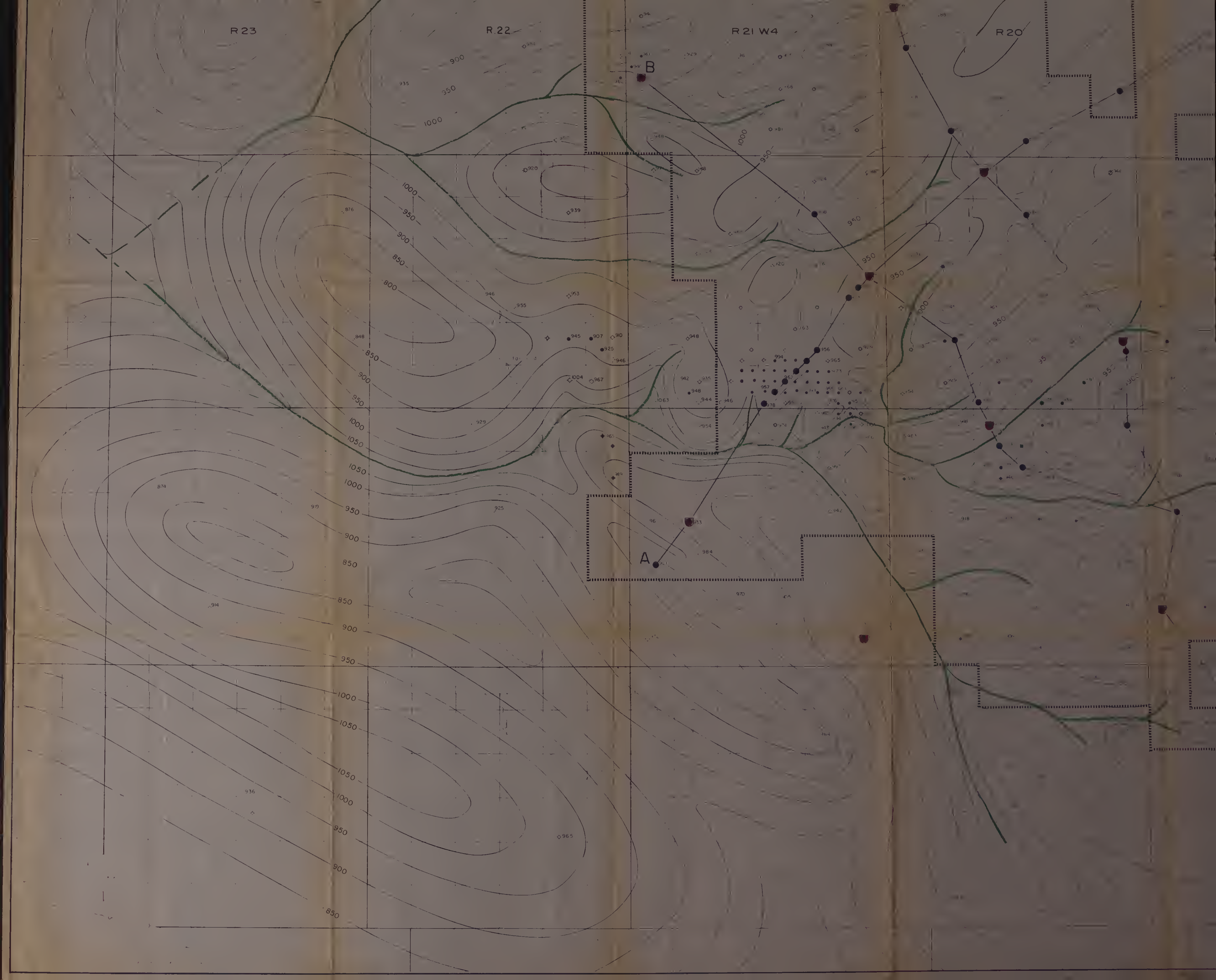
WELLS USED IN STUDY (SEE FIG 2)
HUSSAR FIELD OUTLINE
CONTOUR INTERVAL 50 FT
SCALE 1" = 1 MILE

PATRICK A. ACHAM
UNIVERSITY OF ALBERTA
1971



R23
R.22
R21 W4
R20
A
B
C
850
900
950
1000
800
1050

EROSIONAL EDGE OF PEKISKO FORMATION
R21 W4
R20
R19
T27
T26
T25
T24
C
A1
750
850
900
950
1000


R23
R22
R21 W4
R20
B
A
1000
950
900
850
800
1050

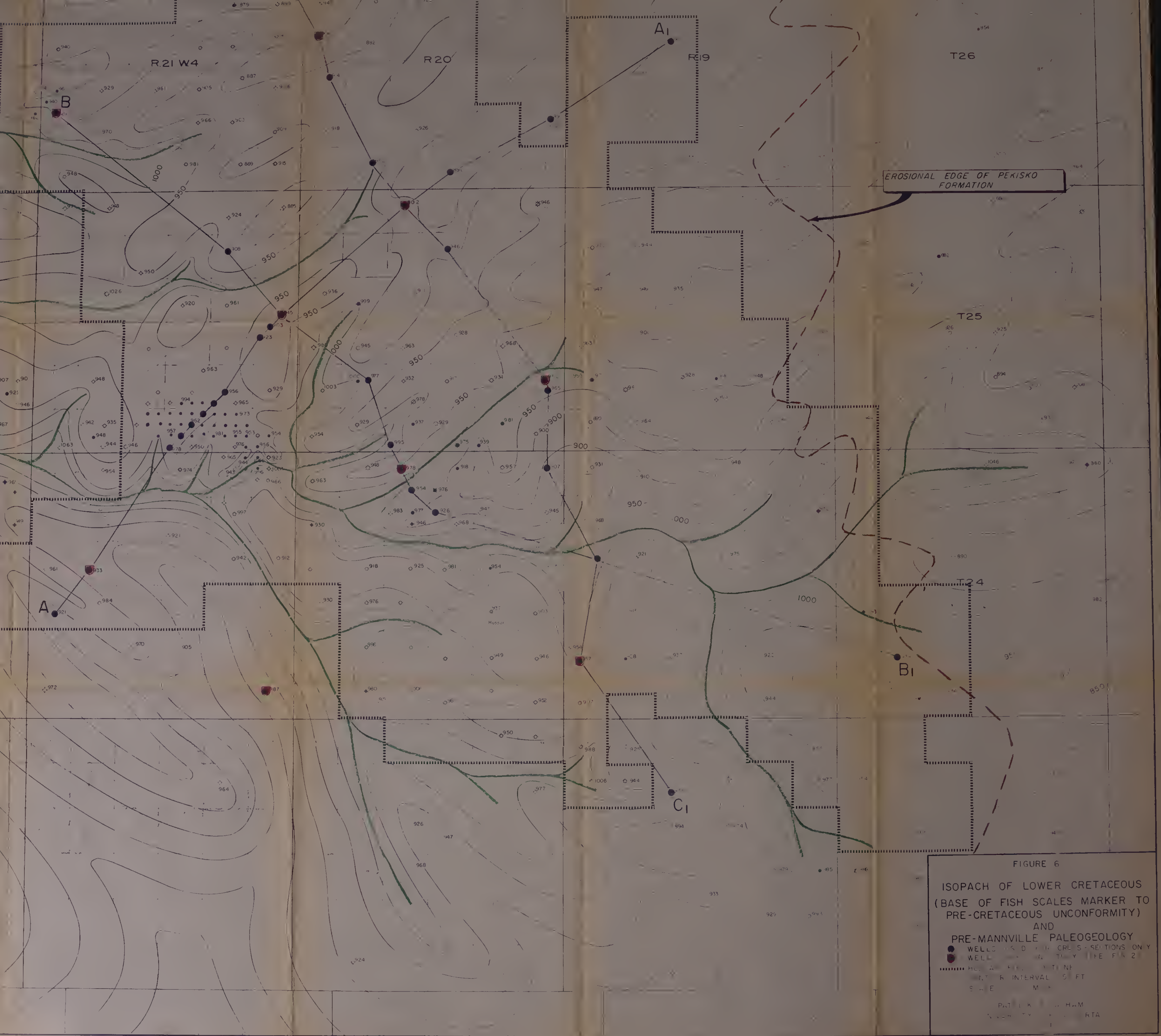
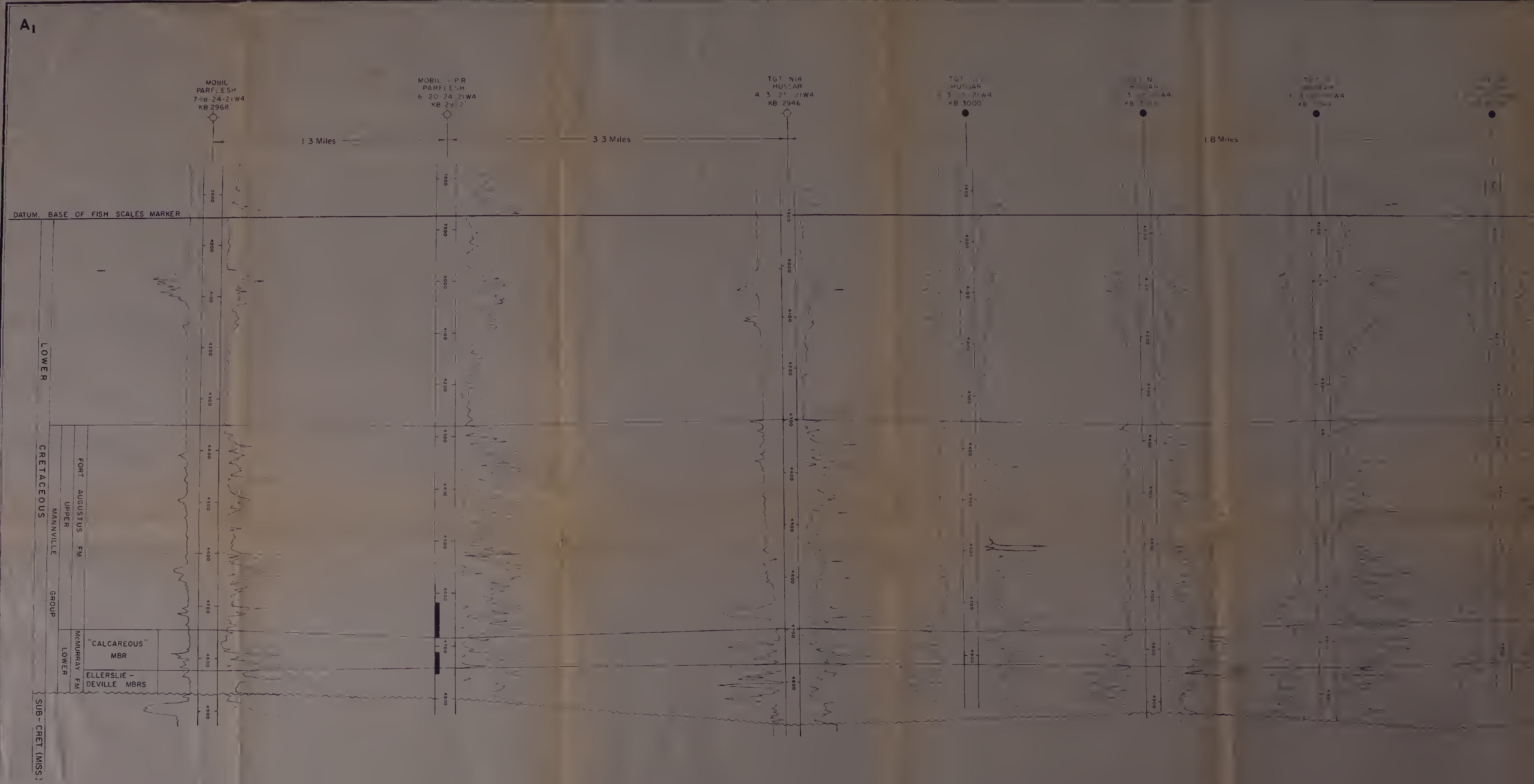
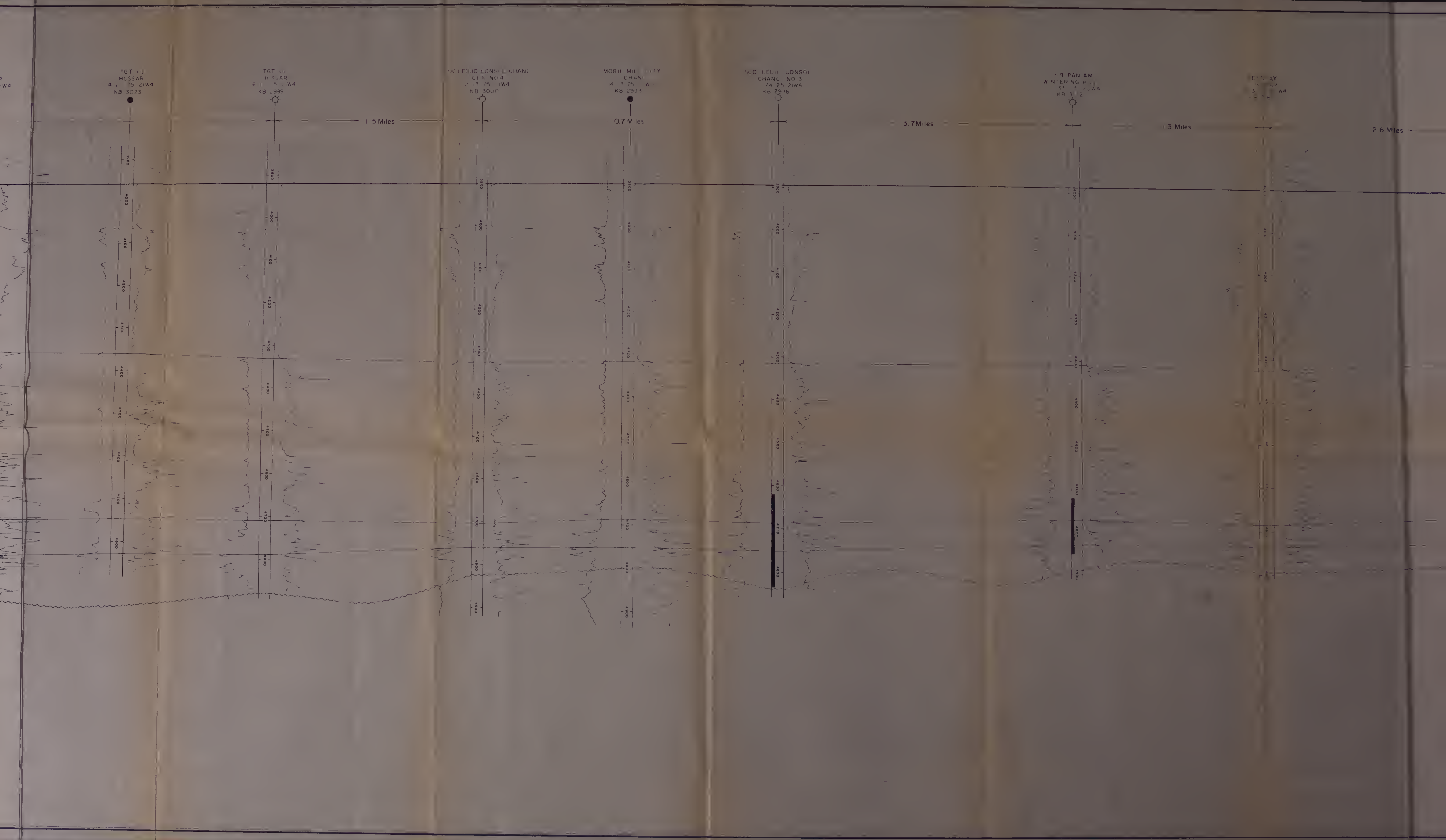


FIGURE 6

ISOPACH OF LOWER CRETACEOUS (BASE OF FISH SCALES MARKER TO PRE-CRETACEOUS UNCONFORMITY) AND PRE-MANNVILLE PALEOGEOLOGY



A1
MOBIL PARFLESH 7-18-24-21W4 KB 2968
TGT N14 HUSSAR KB 2946
1.3 Miles
3.3 Miles
1.8 Miles
DATUM: BASE OF FISH SCALES MARKER
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
FORT AUGUSTUS FM
LOWER
McMURRAY FM
"CALCAREOUS" MBR
ELLERSLIE - DEVILLE MBRS
SUB-CRET. (MISS.)


KB 3023
KB 3000
1.5 Miles
0.7 Miles
3.7 Miles
1.3 Miles
2.6 Miles

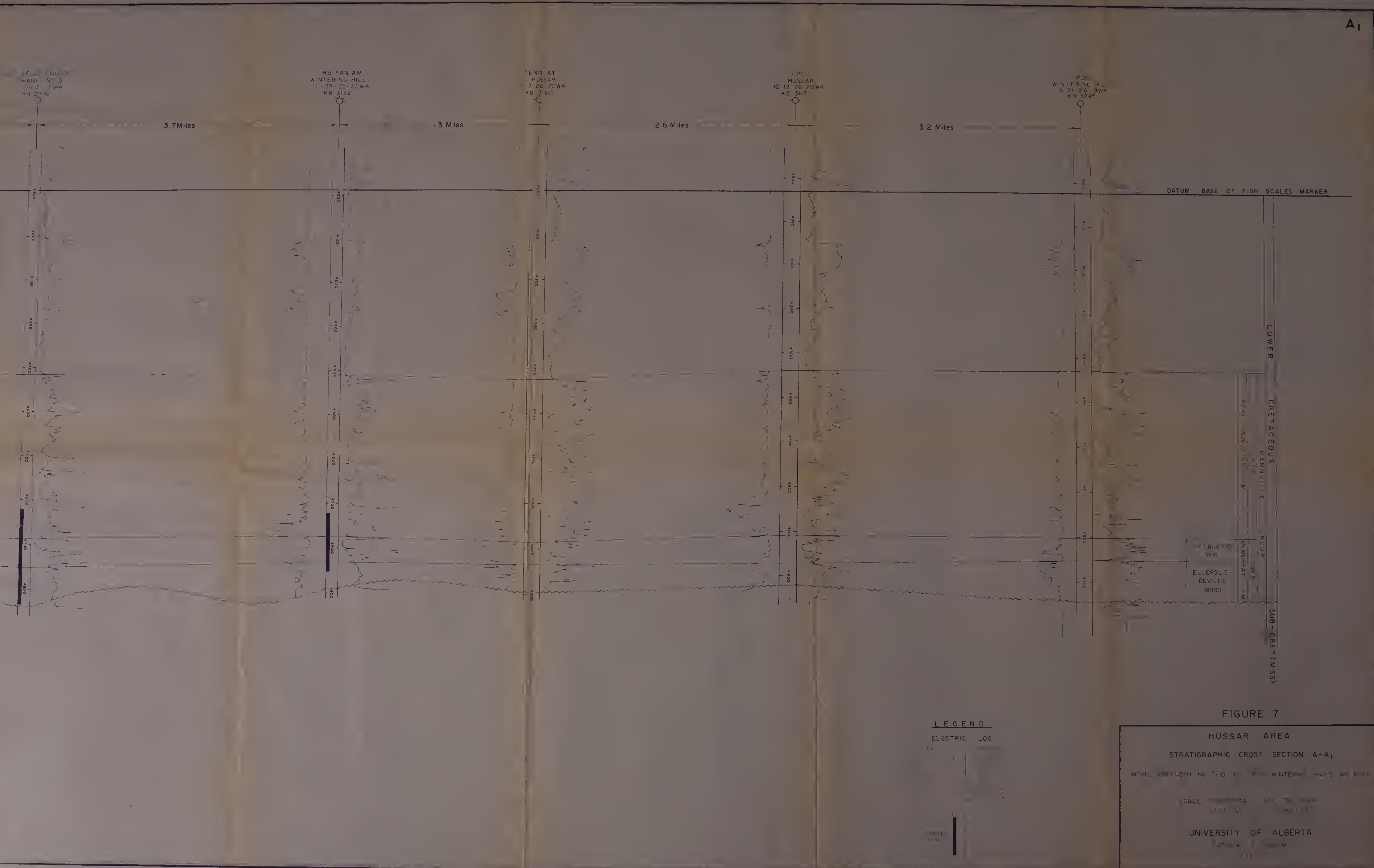
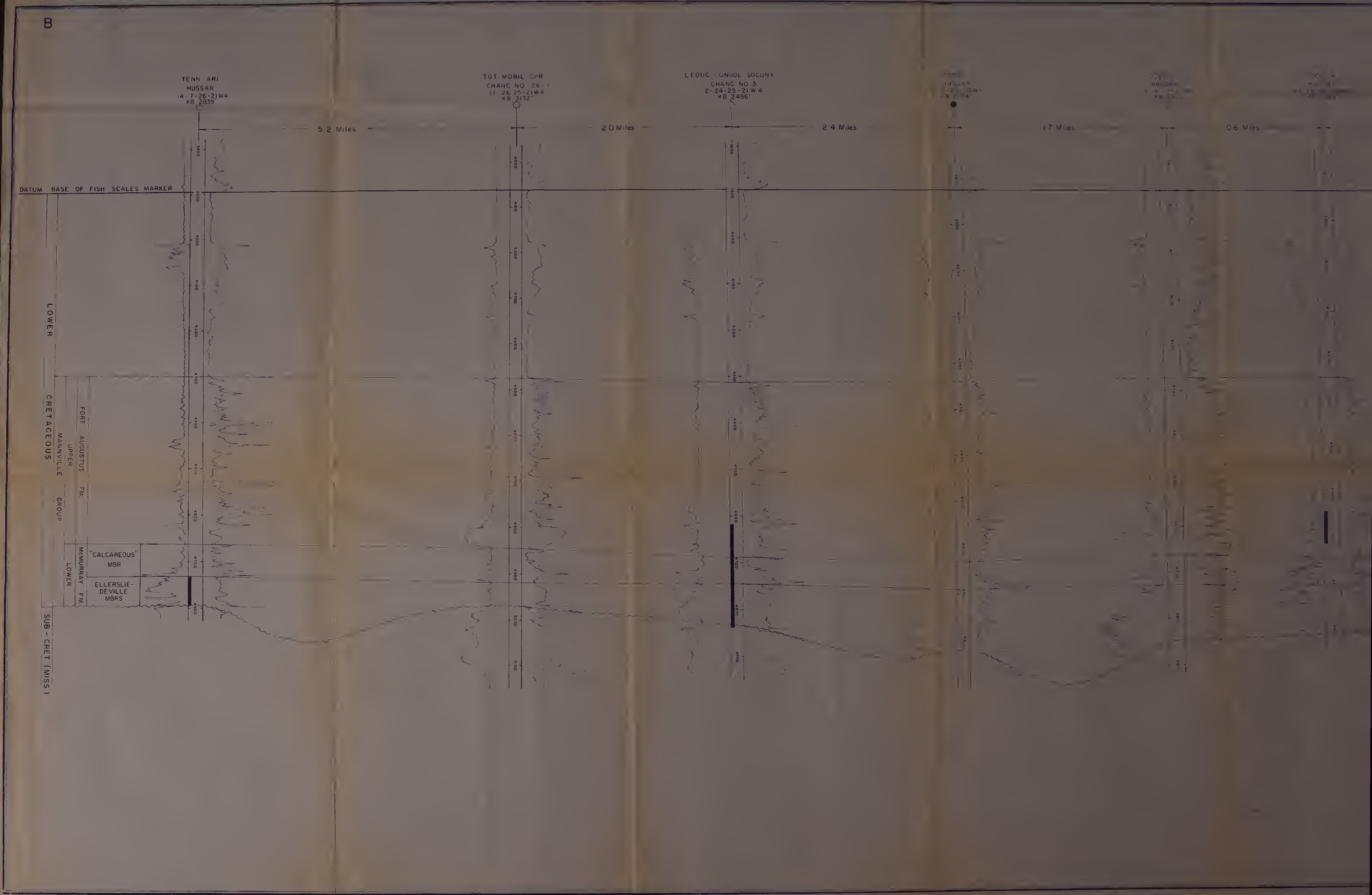


FIGURE 7

HUSSAR AREA

STRATIGRAPHIC CROSS SECTION A-A1

UNIVERSITY OF ALBERTA


B
TENN ARI
HUSSAR
14-7-26-21W4
KB 2839'
TGT MOBIL CPR
CHANC NO. 26-1
11 26 25-21W4
KB 3132'
LEDUC CONSOL SOCONY
CHANC NO 3
2-24-25-21W4
KB 2496'
5.2 Miles
2.0 Miles
2.4 Miles
1.7 Miles
0.6 Miles
DATUM BASE OF FISH SCALES MARKER
LOWER
CRETACEOUS
MANNVILLE GROUP
UPPER
FORT AUGUSTUS FM.
"CALCAREOUS" MBR
McMURRAY FM.
LOWER
ELLERSLIE-DEVILLE MBRS
SUB-CRET (MISS)

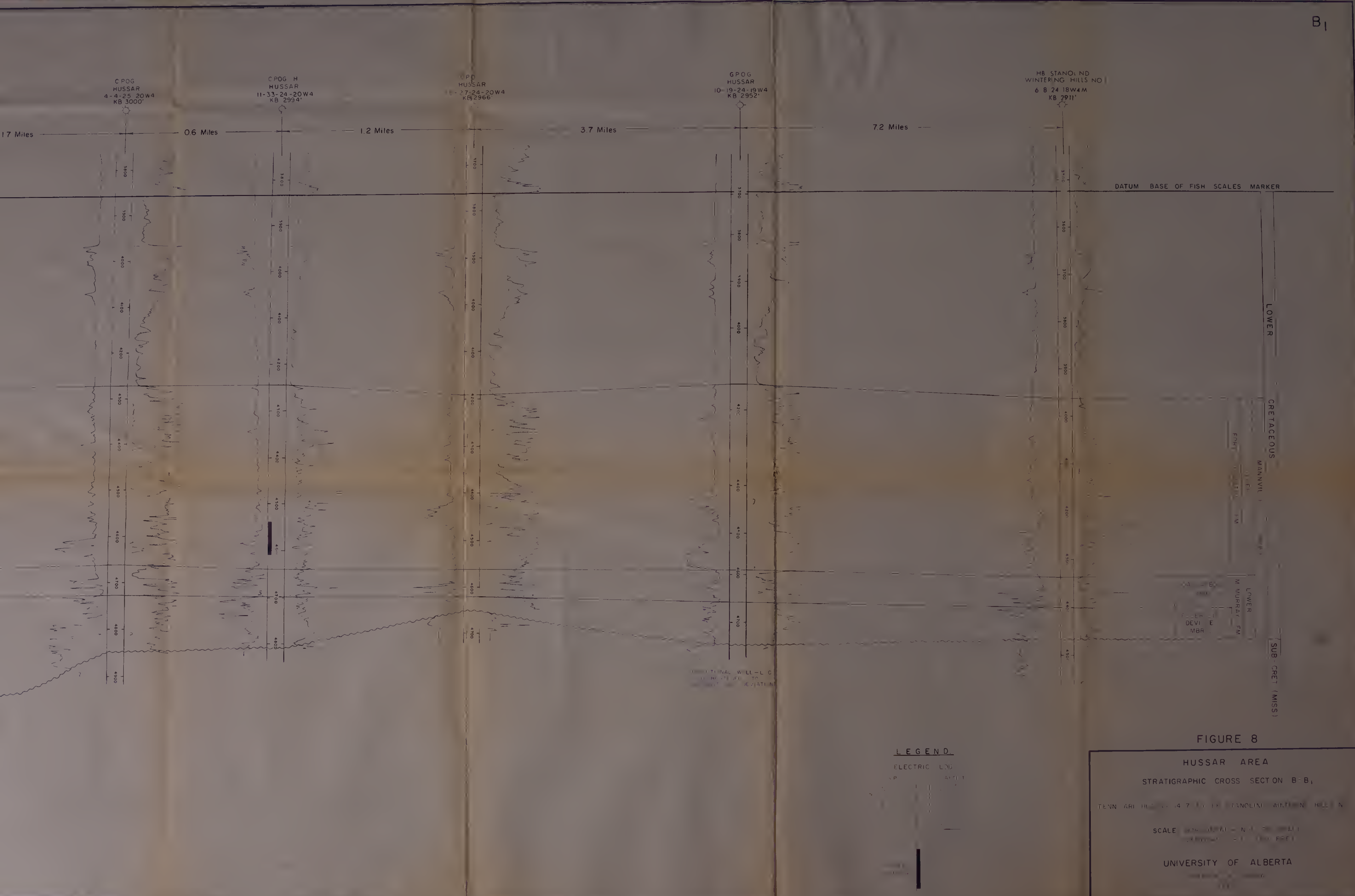
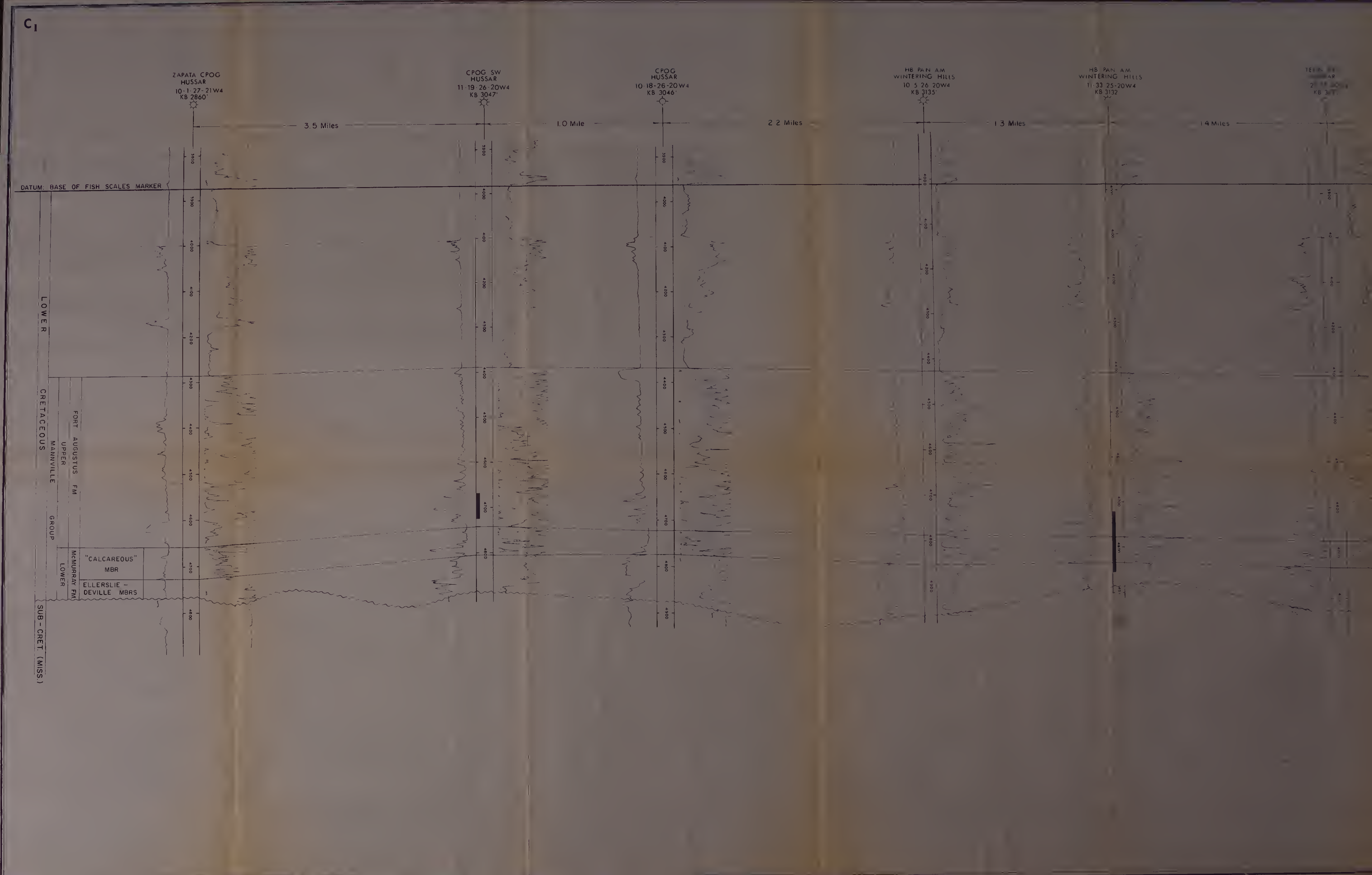


FIGURE 8

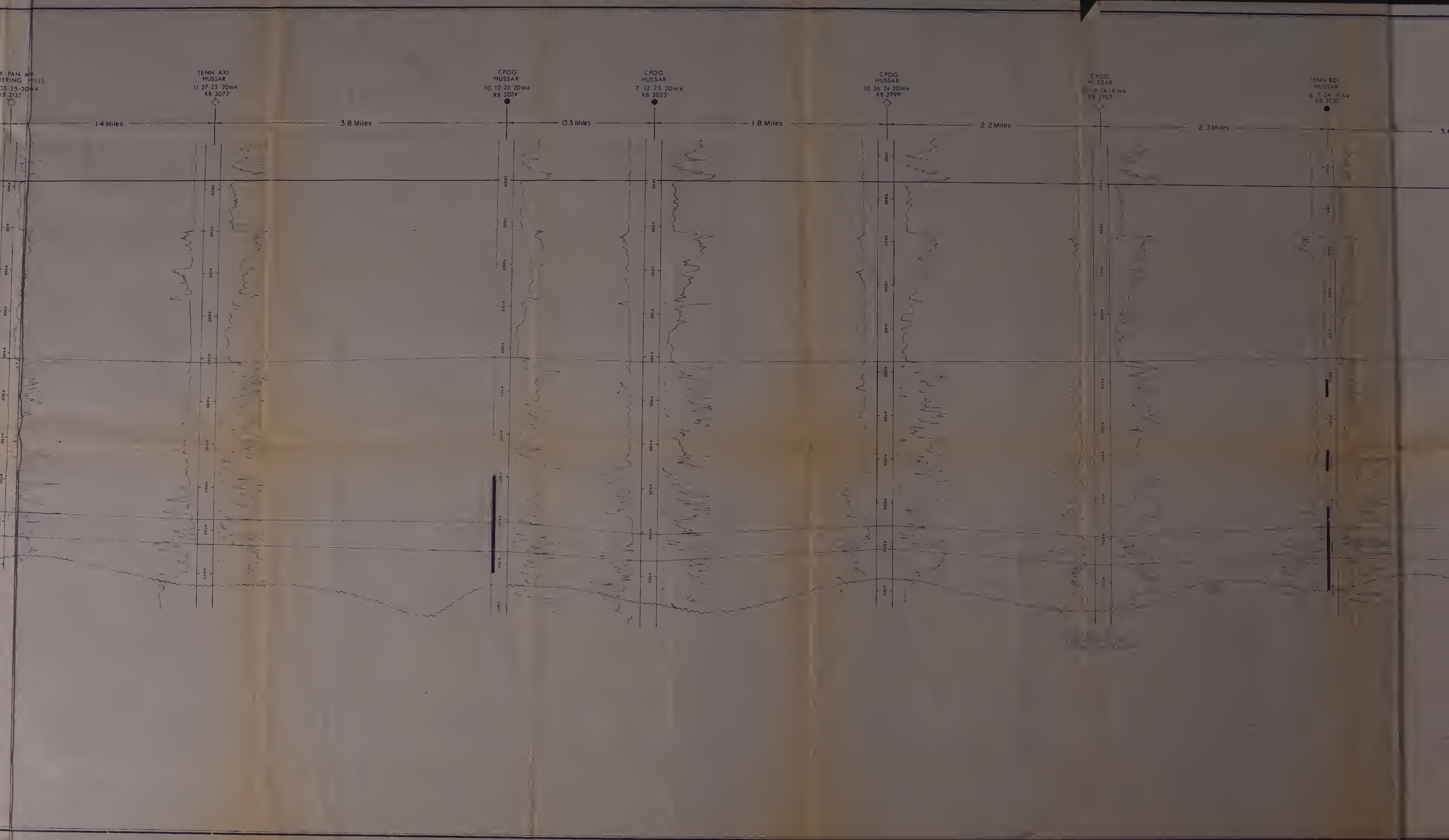
HUSSAR AREA

STRATIGRAPHIC CROSS SECTION B-B1

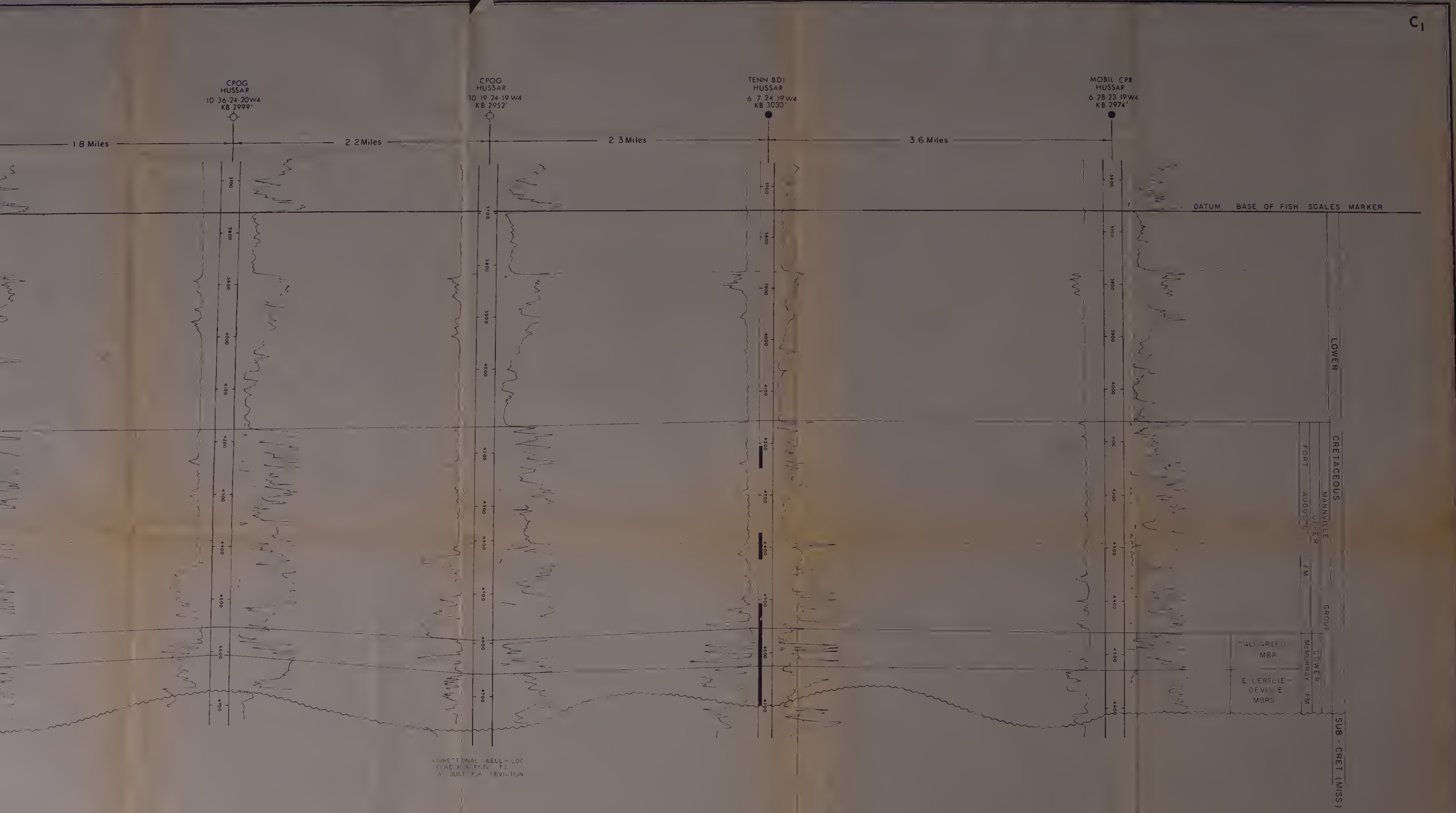
UNIVERSITY OF ALBERTA



C1
ZAPATA CPOG
HUSSAR
10-1-27-21W4
KB 2860'
CPOG SW
HUSSAR
11-19-26-20W4
KB 3047'
CPOG
HUSSAR
10-18-26-20W4
KB 3046'
HB PAN AM
WINTERING HILLS
10-5-26-20W4
KB 3135'
HB PAN AM
WINTERING HILLS
11-33-25-20W4
KB 3132
3.5 Miles
1.0 Mile
2.2 Miles
1.3 Miles
1.4 Miles
DATUM: BASE OF FISH SCALES MARKER
LOWER CRETACEOUS
MANNVILLE GROUP
UPPER
LOWER
FORT AUGUSTUS FM
McMURRAY FM
"CALCAREOUS" MBR
ELLERSLIE - DEVILLE MBRS
SUB-CRET. (MISS.)



TENN AXI
HUSSAR
11 27·25·20W4
KB 3072'
CPOG
HUSSAR
10 12·25·20W4
KB 3024'
CPOG
HUSSAR
7·12 25 20W4
KB 3022'
CPOG
HUSSAR
10 36 24·20W4
KB 2999'
CPOG
KB 2952
HUSSAR
KB 303C
1.4 Miles
3.8 Miles
0.3 Miles
1 8 Miles
2 2Miles
2 3Miles



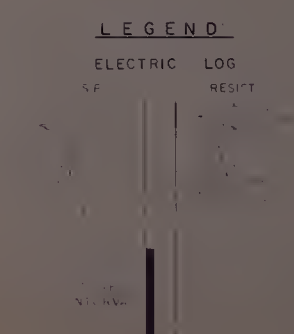


FIGURE 9

HUSSAR AREA

STRATIGRAPHIC CROSS SECTION C-C1

SCALE

UNIVERSITY OF ALBERTA